

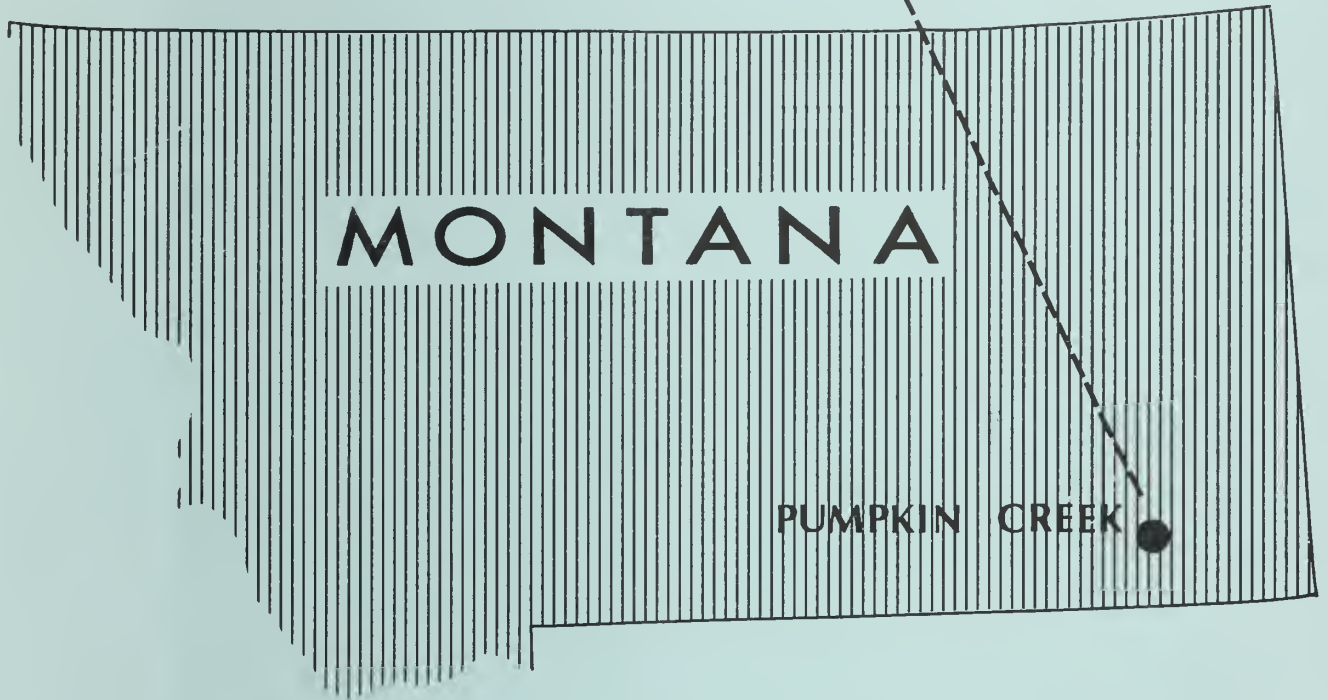
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# Pumpkin Creek Study Area Report



**RESOURCE & POTENTIAL  
RECLAMATION EVALUATION**

Pumpkin Creek Study Area Report  
Published February 1982

The Federal Coal Management Program has been designed as an interagency cooperative effort to meet national energy objectives.

Pumpkin Creek Study Area Report was prepared through the efforts of the U.S. Department of the Interior, principally the Bureau of Land Management, Geological Survey, and Bureau of Reclamation.\* The study effort began in 1978 and was concluded in 1982 with the publication of this report.

The area described in this report has been tentatively determined to be a potential Federal coal development area. The purpose of this

report is to provide information on the area's reclamation potential should coal development occur. This report will assist managers in making final Federal coal leasing decisions.

Limited copies of this report are available from:

Bureau of Land Management  
Montana State Office  
222 N. 32nd St.  
Billings, MT 59107

Please reference the title and report number 21-78 when making a request for this report from the Bureau of Land Management.

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\*In May of 1981, the Secretary of the Interior approved changing the Water and Power Resources Service back to its former name, the Bureau of Reclamation. All references in this publication to the Water and Power Resources Service should be considered synonymous with the Bureau of Reclamation.

<b>REPORT DOCUMENTATION PAGE</b>	1. REPORT NO. BLM-YA-PT-82-010-3420	2.	3. Recipient's Accession No.
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12. Sponsoring Organization Name and Address Bureau of Land Management Montana State Office 222 N. 32nd Street Billings, MT 59107			13. Type of Report & Period Covered Final 77-82  14.
15. Supplementary Notes Prepared under cooperative agreements by Bureau of Land Management, Bureau of Reclamation and Geological Survey			
16. Abstract The purpose of this investigation was to collect baseline data for establishing reclamation objectives and lease stipulations. The report includes data on climate, physiography, geology, coal resources, overburden, hydrology, and greenhouse tests. The study area, located in the northern part of the Powder River Basin, lies within the unglaciated portion of the Great Plains Physiographic Province. Bedrock exposed in the area is the Tongue River Member of the Paleocene Fort Union Formation. Three coalbeds were evaluated - A, Sawyer, and Mackin-Walker. The coal has an apparent rank of Lignite A. Most soils in the study area should yield about 6 to 12 inches of topsoil which is nonsaline, nonsodic, and permeable. Available subsoil materials appear fair to poor in quality. Only 3 percent of the bedrock samples from 11 USBR drill holes were rated suitable for use as supplemental plant media. Streamflow in the study area occurs in response to spring and rainstorm runoff. Shallow ground water occurs in permeable units of the Tongue River Member. Both surface and ground water quality is variable. Surface mining will not significantly affect streamflow outside the study area; however, mining could remove 12 perennial and 25 ephemeral reservoirs. Dissolved solids and sediment concentrations could increase in reservoirs downstream from mine strips. Ground water problems are expected to be minimal. One well could be dewatered and six wells and three springs could be removed by surface mining. Based on the resource data in this report, it appears that restoration of disturbed lands in this study area to their premining uses, though possible, would be more difficult than in other areas in southeastern Montana previously studied under the EMRIA program.			
17. Document Analysis a. Descriptors 0510 Environmental Surveys 0807 Coal Deposits 1407 Reclamation  b. Identifiers/Open-Ended Terms mined-land reclamation, climate, geology, hydrology, soils, vegetation, land use, Powder River Coal Region, Montana  c. COSATI Field/Group			
18. Availability Statement Release unlimited NTIS Springfield, VA 22161	19. Security Class (This Report) unclassified 20. Security Class (This Page) unclassified	21. No. of Pages  22. Price	



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PUMPKIN CREEK STUDY AREA  
PUMPKIN CREEK COALFIELD  
POWDER RIVER COUNTY, MONTANA

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RESOURCE AND POTENTIAL RECLAMATION EVALUATION  
OF  
PUMPKIN CREEK STUDY AREA  
PUMPKIN CREEK COALFIELD  
POWDER RIVER COUNTY, MONTANA

INTRODUCTION

Recent energy shortages have forced our society to seek new domestic sources. Attention has focused on the immense quantities of low sulfur coal that lie within the Rocky Mountain and Northern Great Plains regions. It is the responsibility of the Department of the Interior, principally the Bureau of Land Management, to assist in meeting these energy demands and, at the same time, provide sound reclamation guidelines so that the disturbed lands are restored to an acceptable condition.

PURPOSE

The purpose of this report is to provide information for establishing reclamation objectives and lease requirements. Detailed data is given on geology, coal resources, overburden (soil and bedrock), greenhouse investigations, and hydrology. Less detailed information is provided on climate and physiography.

REPORT OBJECTIVES

1. To analyze and quantify the environmental impacts from surface mining of coal.
2. To provide resource and impact information for leasing site selection procedures as set forth by the Secretary of the Interior.
3. To provide environmental resource information needed to implement effective reclamation and rehabilitation programs and for the development of meaningful lease stipulations as required by the mined land reclamation program.
4. To provide resource and impact information to support State and local regional development and land use planning efforts.
5. To determine the present and potential capability of the soil and bedrock to support and maintain vegetation over known coal deposits.
6. To provide physical and chemical data from which realistic stipulations may be prepared for exploration, mining, and reclamation plans.
7. To provide data needed in the preparation of Environmental Impact Statements, Environmental Analysis Records, and to aid in the review of mining and reclamation plans for proposed land disturbing activities in the vicinity of the study area.

## AUTHORITY

Federal Land Policy and Management Act of 1976 and Surface Mining Control and Reclamation Act of 1977.

## RESPONSIBILITY

### BUREAU OF LAND MANAGEMENT

1. Selects study area for coordinated investigations of climate, geology, hydrology, overburden, and coal resources.
2. Acts as Contracting Officer in the coordination, establishment, and execution of work orders.
3. Procures easements and rights-of-way to conduct the studies.
4. Distributes technical data, reports, and reclamation and rehabilitation recommendations to Bureau of Land Management field offices.
5. Identifies potential postmining land uses.

### BUREAU OF RECLAMATION

1. Conducts a land suitability survey to determine suitability of overburden material (to a 10-foot depth) for use in revegetation of shaped spoils.
2. Conducts drilling operations for the procurement of core samples for coal and soil analysis.
3. Drafts geologic maps.
4. Characterizes and interprets suitability of overburden material as well as substrata immediately below the coal resources for purposes of revegetation.
5. Arranges for greenhouse studies for determining overburden materials' potential for supporting vegetative growth.
6. Conducts mechanical weathering tests of core samples to determine stability of overburden materials.
7. Recommends to District Office, Bureau of Land Management, suitable plant species for use in areas to be reclaimed.
8. Advises District Office, Bureau of Land Management, on reclamation techniques.
9. Advises the Bureau of Land Management on paleontological finds in the study area.

## U.S. GEOLOGICAL SURVEY

1. Assesses reclamation potential based on water available from precipitation, the effects of surface mining on area hydrology, and the measures required to prevent adverse effects on surface and ground water of the area.
2. Collects and interprets data to predict alternative solutions to ground water problems encountered during mining and reclamation.
3. Implements a monitoring system to define baseline conditions and document ground water changes in flow and quality caused by mining and reclamation.
4. Prepares ground water maps.
5. Prepares geologic maps, cross sections, and other geologic illustrations.
6. Describes coalbeds, coal resources, and geology of the study area.
7. Prepares and tabulates coal resources estimates.
8. Prepares a table of analytical results of coal resources.

### GENERAL DESCRIPTION

#### LOCATION

The Pumpkin Creek Study Area is located in southeastern Montana (Powder River County), approximately 15 miles northwest of the town of Broadus. Plate 1 shows the general location. The study area includes 10,880 acres in the following complete sections: T. 2 S., R. 49 E., sections 14, 22, 24, 26, 28, 34, and T. 3 S., R. 49 E., sections 2, 4, 8, 14, 18, 20, 22, 26, 28, 30, and 32 as shown on Plate 2. The majority of surface ownership in the study area is private; the remainder is Federal, as shown on Plate 3. All coal in the study area is federally owned, as shown on Plate 4. Photographs 1 through 5 are views of typical landscape features in the study area.

#### PRESENT LAND USES

The Pumpkin Creek Study Area is used primarily for livestock grazing. Limited dryland and irrigated farming occurs on the private surface. In the northern part of the study area, scattered ponderosa pine and juniper occur, but there is no known commercial timber production. Portions of the study area provide superior habitat for wildlife with a high species diversity.

#### POSTMINING LAND USES

Postmine land use is anticipated to be livestock grazing, with limited dryland or irrigated farming.

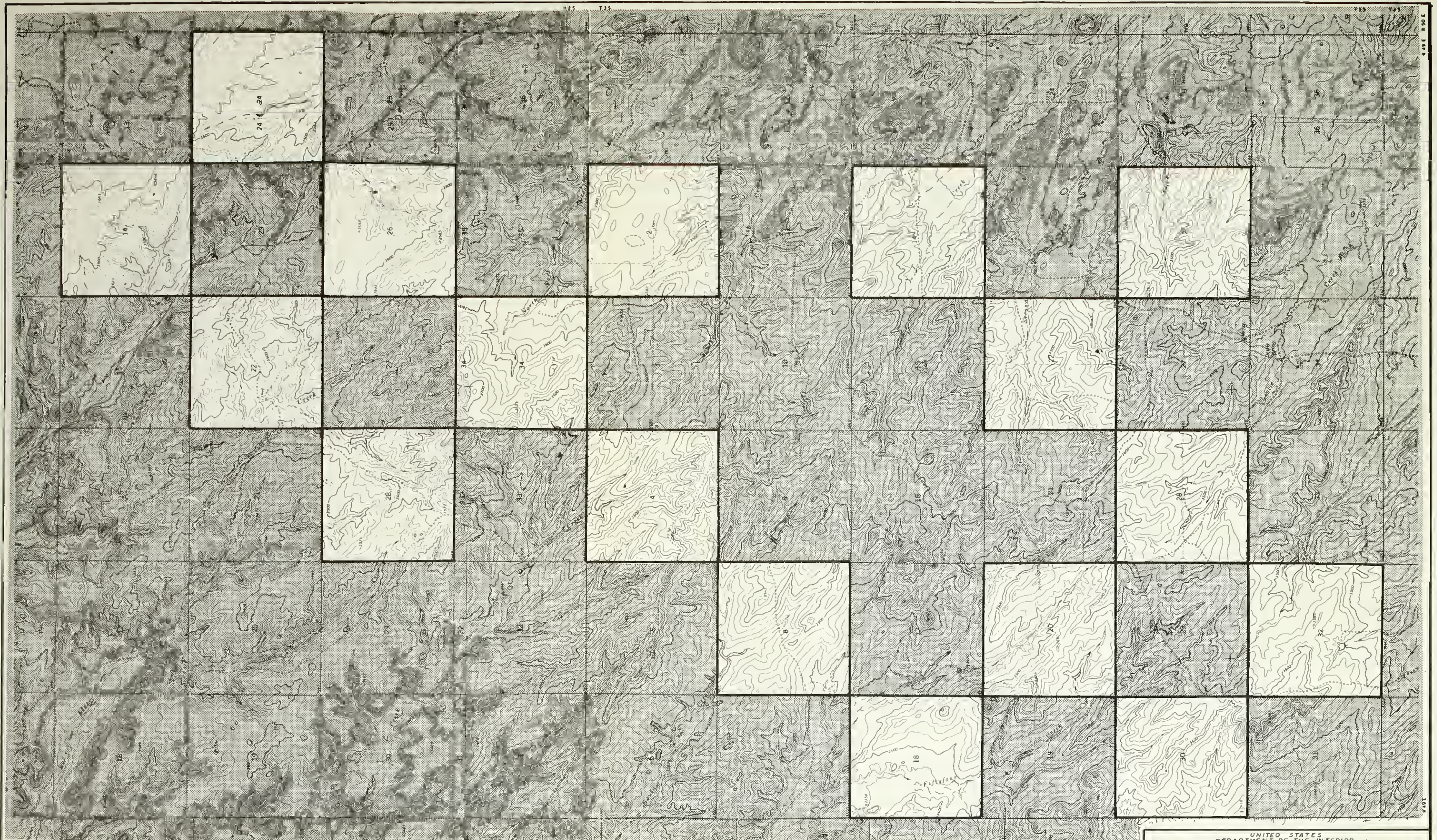
## RULES GOVERNING MINING AND RECLAMATION OPERATIONS

In Montana, coal mine operators must comply with all established rules pursuant to the Montana Strip and Underground Mine Reclamation Act (1973). These rules are presented in Appendix A of the "Montana Permanent Program" for regulating surface and underground mining activities.<sup>1/</sup>

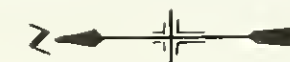
The Montana Department of State Lands is the regulatory agency responsible for administering this program.

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<sup>1/</sup> The Montana Permanent Program was approved by the U.S. Department of the Interior, Office of Surface Mining, on April 1, 1980.



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NOTE  
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UNITED STATES DEPARTMENT OF THE INTERIOR WATER AND POWER RESOURCES SERVICE RESOURCE AND POTENTIAL RECLAMATION EVALUATION	
PUMPKIN CREEK STUDY AREA PUMPKIN CREEK COALFIELD	
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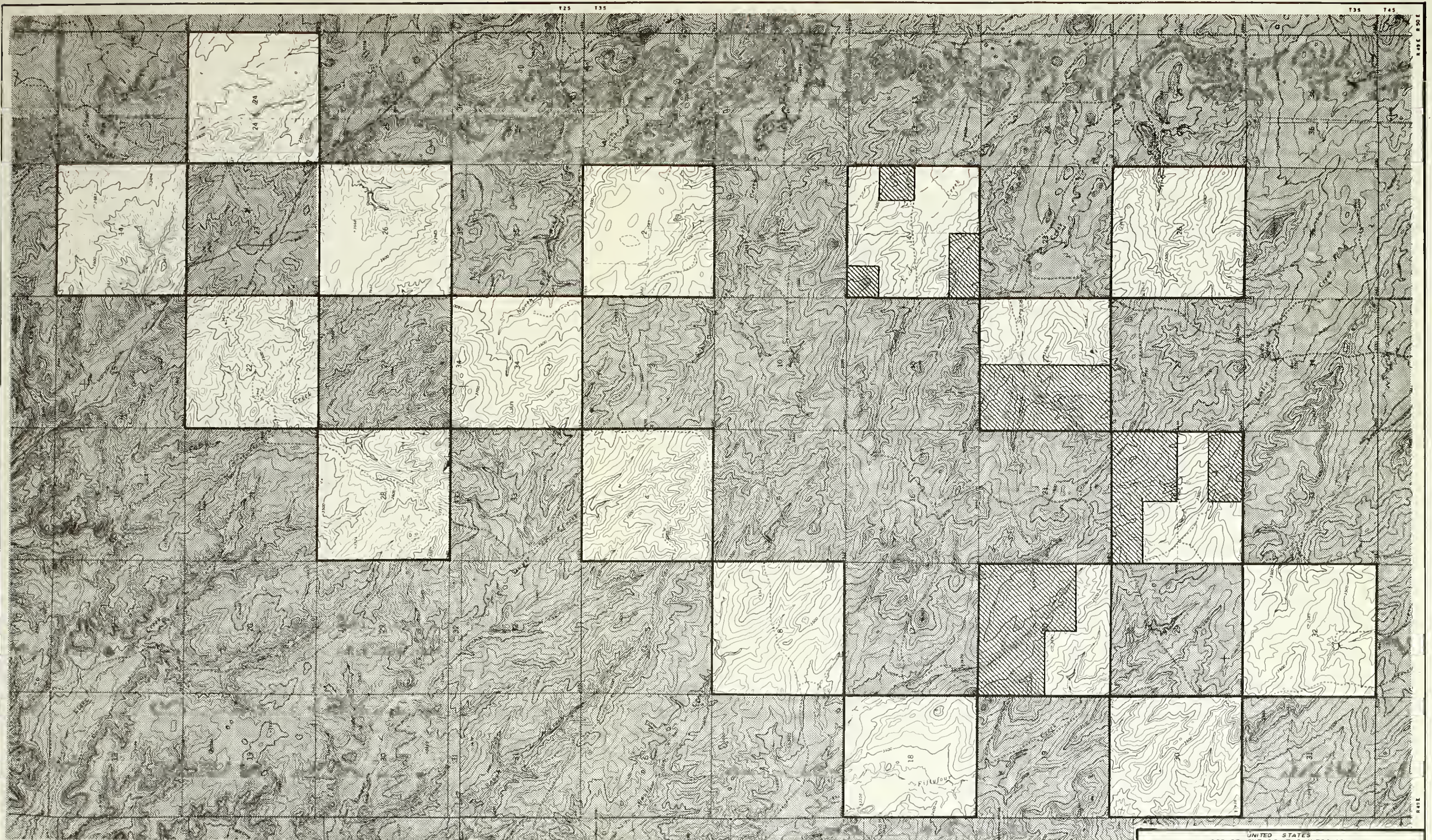
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The Montana Department of State Lands is the regulatory agency responsible for administering this program.

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<sup>1/</sup> The Montana Permanent Program was approved by the U.S. Department of the Interior, Office of Surface Mining, on April 1, 1980.



NOTE  
Study area not shaded

LAND OWNED BY THE  
FEDERAL GOVERNMENT



UNITED STATES  
DEPARTMENT OF THE INTERIOR  
WATER AND POWER RESOURCES SERVICE  
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PUMPKIN CREEK STUDY AREA  
PUMPKIN CREEK COALFIELD  
LAND STATUS MAP

DESIGNED BY WESTMAN FIELD APPROVAL  
DRAWN BY ALLSOP TECHNICAL APPROVAL  
CHECKED APPROVED

BILLINGS, MONTANA MARCH, 1961 1305-600-208

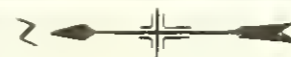
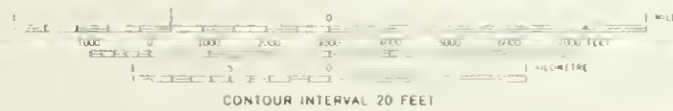
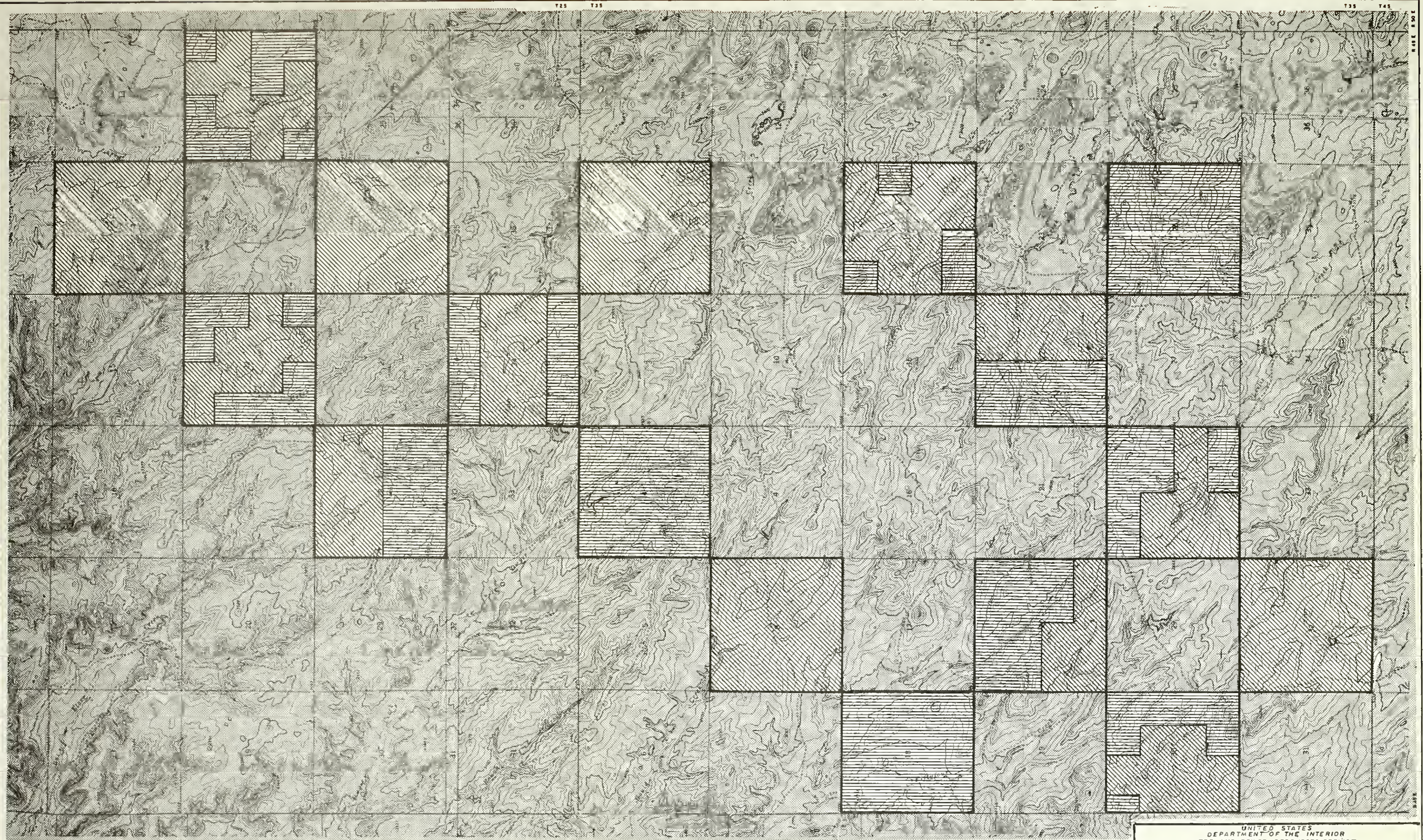
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The Montana Department of State Lands is the regulatory agency responsible for administering this program.

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<sup>1/</sup> The Montana Permanent Program was approved by the U.S. Department of the Interior, Office of Surface Mining, on April 1, 1980.



NOTE  
Study area not shaded

MINERALS OWNED BY  
THE FEDERAL GOVERNMENT

SYMBOLS	MINERAL RIGHTS
	All minerals
	Coal only

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
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RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PUMPKIN CREEK STUDY AREA  
PUMPKIN CREEK COALFIELD  
MINERAL STATUS MAP

DESIGNED G. WESTMAN	FIELD APPROVAL _____
DRAWN L. E. ALLSOP	TECHNICAL APPROVAL _____
CHECKED _____	APPROVED _____

BILLINGS, MONTANA MARCH, 1981 1305-600-209





View looking southeast from a high knob west of DH-77-104. Fence runs north-south between sections 31 and 32, T. 3 S., R. 49 E., Pumpkin Creek Study Area, Montana, 9/20/77. Water and Power Resources Service Photograph No. P1305-600-21.





View looking toward clinker-capped knobs southeast of DH-77-107. Taken from S $\frac{1}{4}$ , section 14, T. 3 S, R. 49 E., Pumpkin Creek Study Area, Montana, 9/19/77. Water and Power Resources Service Photograph No. P1305-600-22.





View looking north from near DH-77-106, SE $\frac{1}{4}$ , section 4, T. 3 S., R. 49 E.,  
Pumpkin Creek Study Area, Montana, 9/19/77. Water and Power Resources Service  
Photograph No. P1305-600-23.





View looking east from a high knob west of DH-77-104. Fence runs north-south between sections 31 and 32, T. 3 S., R. 49 E., Pumpkin Creek Study Area, Montana, 9/20/77. Water and Power Resources Service Photograph No. P1305-600-24.





View looking northeast from a high knob west of DH-77-104. Fence runs north-south between sections 31 and 32, T. 3 S., R. 49 E., Pumpkin Creek Study Area, Montana, 9/20/77. Water and Power Resources Service Photograph No. P1305-600-25.



## OBJECTIVE OF RECLAMATION

Montana law presently requires the coal mine operator to restore all disturbed areas, "in a timely manner, either to conditions capable of supporting the uses they were capable of supporting before any mining or to conditions capable of supporting approved alternative land uses. Alternative land uses may be approved by the Department of State Lands after consultation with the landowner or the land-management agency having jurisdiction over the lands . . ." /Rule XVI, 5(c) pursuant to "The Montana Strip and Underground Mine Reclamation Act" - Montana Permanent Program/.

Unless an alternative postmining land use is desired by the landowner(s) and approved by the Montana Department of State Lands, the main objective of reclamation in the Pumpkin Creek Study Area would be to establish a diversive vegetative cover with an interspersion of vegetative types over the reclaimed land capable of supporting livestock and wildlife. The integrity of the visual resource should be maintained.

## PHYSICAL PROFILE

### CLIMATE<sup>1/</sup>

The Pumpkin Creek Study Area has a continental-type semiarid climate characterized by cold winters, warm summers, and large variations in seasonal precipitation.

#### Precipitation

The mountains along the Continental Divide cause air masses to rise and precipitate their moisture, primarily on the windward slopes. The air masses then warm and dry as they descend the leeward slopes. As a result, a "rain shadow" is created over the eastern Montana counties. The average annual precipitation in these counties is about 13 inches.

The following mean monthly and annual precipitation were recorded during the period 1937-1961 at Broadus, Montana (15 miles southeast of the study area):

#### Month

<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>Aug</u>	<u>Sept</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec</u>	<u>Annual</u>
------------	------------	------------	------------	------------	-------------	-------------	------------	-------------	------------	------------	------------	---------------

#### Inches

.50	.46	.80	1.24	2.24	3.11	1.39	1.04	1.05	.88	.67	.43	13.8
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Approximately 73 percent of the annual precipitation falls during the period April through September. May and June are the wettest months, receiving 39 percent of the annual precipitation.

Snowfall is most common between October and late April. However, small amounts may also occur in May, June, and September. Although a continuous snow cover is not common in this area, the total moisture provided by snowfall may comprise as much as 32 percent of the annual precipitation.

#### Temperature

Based on data recorded at Broadus, Montana, between 1937 and 1961, temperature extremes of 108°F in summer and -42° in winter may occur in this area.

Generally, less than 30 days a year have a maximum temperature over 80°F, and 20 days or less have a minimum temperature less than 0°F.

The mean monthly and annual temperatures recorded at Broadus (1937-1961) are as follows:

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<sup>1/</sup> Data in this section is taken from: Soil Survey of Powder River Area, Montana, USDA-SCS, 1971.

Month (°F)

<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>Aug</u>	<u>Sept</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec</u>	<u>Annual</u>
18.9	23.5	31.6	44.4	54.8	62.8	71.6	70.1	58.6	47.8	32.2	24.0	45.1

The weather station at Broadus records a range of 100 to 128 days when the temperature exceeds 32°F (frost-free period) and 144 days when the temperature is above 28°F (growing season for hardy crops). Growth of native range plants is rapid during May and June. However, by mid-July the available soil moisture is usually depleted and the plants mature or become dormant.

Other Climatic Factors

Thunderstorms and occasional destructive hailstorms, most common in July and August, are caused by local convection heating. A semi-permanent low pressure area in the southwestern United States results in a flow of unstable air into the area, contributing to this phenomena. Damage to range plants from hail and heavy rainfall is usually minimal. However, the more intense storms may result in severe soil erosion, especially in steeply sloping and sparsely vegetated areas.

Considerable sunshine can be expected in all seasons, except for the annual rainy period in May and June and occasional cloudy periods in November and December.

Effect of Climate on Revegetation

Climate will be a limiting factor for revegetation of disturbed land with adapted plant species.

Soil moisture is relatively high during the early part of the growing season and plant growth is rapid. This is favorable for the establishment of spring planted grasses. It also promotes rapid growth of fall planted grasses, which should be well established before erosive thunderstorms occur in the summer. Plants seeded in the fall or early spring should be established before the available moisture is depleted in July.

Hazardous climatic factors that may adversely affect revegetative efforts in this study area include: (1) below normal or uneven distribution of precipitation, especially during the growing season, (2) intense thunderstorms and/or strong winds that cause erosion, (3) late spring freezes, and (4) depletion of soil moisture by wind. More detailed investigations will be necessary prior to mining to more accurately determine probabilities of occurrence of these factors. This data can then be used to predict best possible seeding times for revegetation.

## PHYSIOGRAPHY

The Pumpkin Creek Study Area is located in the northern part of the Powder River Basin in Powder River County, Montana. This basin lies within the unglaciated Missouri Plateau section of the Great Plains Physiographic Province. Pumpkin Creek, a tributary of the Tongue River, forms the western border of the study area. The town of Broadus, Montana, is located about 15 miles southeast of the study area.

The surface relief in this study area is about 350 feet, with elevations ranging from 3700 feet in the south-central portion of the area to 3350 feet in Pumpkin Creek valley in the northwestern corner of the area. Surface gradients are variable, ranging from 0 to 2 percent in Pumpkin Creek valley to greater than 35 percent in the semibadlands terrain in the uplands.

Topographic features occurring in this study area include small valleys, fans, swales, relatively smooth side slopes, and smooth rolling ridges. Several buttes and steep, rocky outcrops also occur in the area.

Drainage of the study area is accomplished through an extensive system of branching natural drains (dendritic pattern). The general flow of drainage is northward to the Yellowstone River via Pumpkin Creek and the Tongue River.

## GEOLOGY

### Regional Geology

The Pumpkin Creek Study Area is located in the northern part of the Powder River Basin in southeastern Montana. This basin, a part of the unglaciated portion of the Great Plains Physiographic Province, is about 225 miles long, extending from the Yellowstone River in Montana to the North Platte River in Wyoming. It is about 90 miles wide, bordered on the west by the Bighorn Mountains and on the east by the Black Hills. Structurally, the basin is an asymmetrical syncline with a northwestward trending axis. An estimated 18,000 feet of sediments overlies the basement complex in the deepest part of the basin north of Glenrock, Wyoming.

The geologic history of the area since Precambrian time includes periods of deposition, deformation, and erosion. During the Paleozoic and Mesozoic Eras, a sequence of carbonates, sandstones, and shales were deposited throughout Montana and Wyoming. Thickness of these sediments on the west side of the basin varies from 9,000 feet near Yellowtail Dam to 11,500 feet near Buffalo, Wyoming. About 6,500 feet of Paleozoic and Mesozoic sediments are present in the Black Hills area on the east side of the basin.

The area was relatively stable during these periods, with deposition generally occurring in a marine environment. Deformation of these strata began with the Laramide Revolution near the close of the Mesozoic Era (Late Cretaceous), at which time mountain masses such as the Bighorns and Black Hills were uplifted. Uplift continued through the Paleocene and gradually ended in Eocene time. Materials stripped from the mountains were deposited in fans or sheets across the basin floors, gradually burying the flanks of the mountains in their own debris. By the middle of the Cenozoic Era, the basins were largely filled and the mountains peneplained. In Pliocene time, a broad regional uplift occurred and continued intermittently into Pleistocene time. This uplift raised the previously developed peneplain surface to elevations of about 10,000 feet in the Bighorn Mountains. Streams rejuvenated by the uplift excavated the basins and exhumed the buried mountain masses.

Today, Precambrian rocks are exposed in the cores of the Black Hills and Bighorn Mountains. These rocks are surrounded by sediments of Paleozoic and Mesozoic Age. The central part of the basin is filled with Cenozoic (Tertiary) sediments. Plate 5 is a generalized map of the regional geology of the basin area.

### Area Geology

#### Investigations

All of the Pumpkin Creek Study Area was mapped by the U.S. Geological Survey. Maps are included in the Coal Resources section of this report.

Drilling investigations in the study area were started by the Bureau of Reclamation during November 1976. Heavy snows during December of that year halted all activity. Work was then resumed during August 1977 and continued through September 1977.

Ten drill holes were cored to depths ranging from 134.0 to 314.5 feet. Continuous cores were obtained from all holes for geologic logging and for the selection of coal and overburden samples for laboratory analyses. Locations of the drill holes are shown on Plates 16 and 17 (following pages 16, 18). Detailed geologic logs of all drill holes are included on Plates 6 through 15 (Appendix B).

All overburden cores were tested for suitability in reconstructed profiles by the Bureau of Reclamation Soils Laboratory in Bismarck, North Dakota. Test results are graphically shown on the geologic logs.

### Stratigraphy

Sedimentary units exposed in the Pumpkin Creek Study Area are Paleocene to Holocene in age. Plate 17 (following page 18) is a geologic map of the study area. Three unconsolidated Pleistocene or Holocene age units and one Paleocene bedrock unit have been mapped. Brief descriptions of the stratigraphic units are:

#### Holocene

Alluvium (Qa) - unconsolidated clay, silt, sand and lenses of gravel in and adjacent to the principal streams. Areas include alluvial valley floor, stream channel, flood plain and low alluvial terrace deposits.

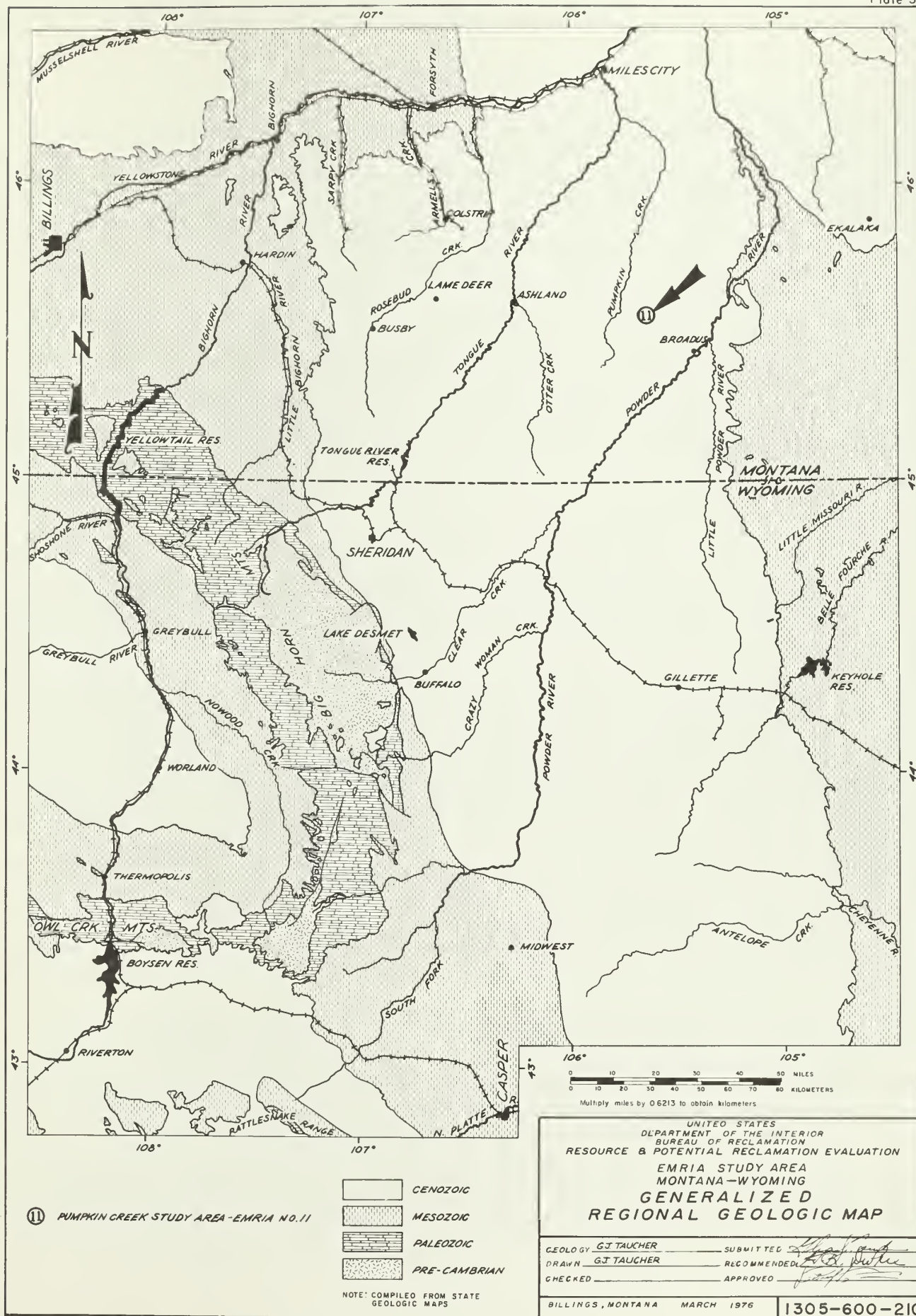
Other Alluvial Deposits (Qao) - unconsolidated clay, silt, sand and lenses of gravel adjacent to valley floors of principal streams, in and adjacent to tributary streams, and in the upper reaches of the principal streams. Includes upper stream channel, older flood plain, alluvial terrace deposits, and, locally, some alluvial fan and slopewash deposits.

#### Holocene and Pleistocene

Terrace Deposits (Qt) - unconsolidated silt, sand and gravel. Contains pebbles, cobbles and boulders of clinker, siltstone, silty limestone, and sparse petrified wood. Terrace levels lie as much as 160 feet above the principal streams.

#### Paleocene

Tongue River Member - Fort Union Formation (Tft) - light to dark gray, yellowish gray and tan sequence of alternating units of mudstone, siltstone, sandstone, shale, carbonaceous shale, silty limestone and coal. Investigations reveal that the top part of the member has been eroded from the study area. A thickness of approximately 800 feet is still represented.





## Clinker

Striking features in the Fort Union Formation are the resistant clinker zones, locally called "scoria," that cap ridges and buttes or armor valley walls. The clinker is a fused or baked rock produced by the burning of coalbeds along and back from the outcrops. In places where the heat was sufficiently intense, the clinker has been fused to a dark gray, lightweight rock similar in appearance to vesicular basalt. Near the outer edge of thermal metamorphism, the rock is disoriented, baked and reddish orange in color. Alteration of the overlying material is roughly proportional to the thickness of coal that has burned. A coalbed 30 feet thick will produce clinker zones 50 to 75 feet thick. The clinker is highly permeable and locally supplies water for springs and wells. Subsurface investigations at other sites show that not all coal has burned beneath clinkered areas. An extensive drilling program would be required to locate and delineate any such deposit. For the purpose of this report, the contact between baked and unbaked rock is assumed to be vertical and that all coal underlying clinker has burned.

## Structure

The Pumpkin Creek Study Area is located on the east flank of the Powder River Basin. Regional dip is approximately 1 degree or less to the west and southwest. Local undulations occur within rock units and are probably the result of differential compaction.

Three normal faults were mapped in the study area by the U.S. Geological Survey (Plate 17). The most significant of the faults is in the southern part of the area. It strikes northwest and has a displacement of about 50 feet or less. It can be traced for approximately 4 miles. The other faults are in the northwestern part of the study area. They strike north-northwest and are limited in displacement and extent.

## Paleontology

Both plant and invertebrate fossils are present in the Pumpkin Creek Study Area. They represent a continental environment with permanent bodies of fresh water.

The plant fossils are represented by poorly silicified wood found as large stumps in the Tongue River Member or as petrified wood fragments in terrace deposits. Several broken and scattered tree stumps of at least 4 feet diameter are present in the area. Invertebrate fossils are present in areas of the Tongue River Member. The U.S. Geological Survey made a collection of these fossils from the NW $\frac{1}{4}$  NW $\frac{1}{4}$  Sec. 20, T. 3 S., R. 49 E. (USGS Cenozoic Loc. D 1287 NM). They were identified by John H. Hanley as bivalves Plesielliptio pricus (Meek and Hayden) and Pisidium spp. indet., gastropods Campeloma nebrascensis nebrascensis (Meek and Hayden), Lioplacodes limnaeformis (Meek and Hayden), and Lioplacodes nebrascensis (Meek and Hayden), and the ostracode Ostracoda spp. indeterminate.

## Engineering Geology

### Stability of Excavation Slopes

Engineering property tests were not conducted on bedrock samples from the Pumpkin Creek Study Area, but physical property test results should be similar to those of Fort Union Formation samples tested at the Otter Creek Study Site, Montana (EMRIA Report No. 1).

Much of the bedrock at the Pumpkin Creek Study Area consists of bentonitic shales which are susceptible to minor shrinking and swelling. Shear strengths of the material are low, especially in a saturated condition. Slides could easily develop adjacent to high walls in surface mines, particularly along beds of weak, plastic, carbonaceous shales which are typically cut by inherent slickensides. Adequate drainage will have to be maintained to relieve pore water pressure in the overburden as mine excavations progress.

Saturated, uncemented siltstones and fine grained sandstones will readily erode and flow into excavations. This problem is sometimes encountered in drilling when the walls of holes collapse or slough. Depth of excavation will be limited by the water table until these materials are dewatered.

Excavation slopes will vary considerably between mine sites and will be dependent on exposure time, moisture conditions, material types and depth of cut. Detailed engineering studies of the overburden will be required at each location for use in determination of designed slopes.

Studies conducted at the Otter Creek site indicate that disturbed overburden (spoil banks and piles) should have slopes not greater than 4 to 1 with berms of 50 to 100 feet in width designed on the slope surface.

### Stability of the Present Landscape

In its present undisturbed state, the Pumpkin Creek Study Area experiences no problems with land stability. Landslides do not occur because of the gentle slopes and subsidence is not a problem.

### Overburden Expansion

Overburden volumes expand as the materials are broken up during mining. The increase in volume (bulking or swell) differs for various types of soil and rock. Soft sandstones and shales in the Fort Union Formation will probably expand about 25 percent. In some cases, the surface of the replaced overburden will be higher after mining than the ground surface was before disturbance.

## Instability of the Postmining Landscape <sup>1/</sup>

Three types of instability are common on reclaimed coal mined areas in the Northern Great Plains. They are: (1) area-wide settling; (2) localized collapse; and (3) piping. Each type of instability is affected by variables in the postmining landscape. These include the physical and chemical characteristics of the overburden, methods and equipment used in stripping and contouring operations, and the season when these activities occur.

Area-wide settling is common in most postmining landscapes, but appears to cause only minimal disruption. This settlement will generally be most pronounced during the first year and will continue at a decreasing rate with time.

The texture of the overburden will have a marked influence on settlement. Fine-textured (clayey) overburden usually results in more blocky and, initially, more porous spoils than does coarse-textured (sandy) overburden. Therefore, a lesser degree of settlement is expected in areas of largely sandy spoils than in areas of clayey spoils.

Equipment is also a critical factor. Settlement is significantly less in scraper-contoured areas than in dozer-contoured areas, especially if contouring is conducted in mid-winter. This is because a greater degree of compaction is achieved in scraper-contouring operations than in dozer-contouring operations.

Local collapse features develop soon after contouring and usually complete development within a year. They commonly occur in precontouring valley areas where frozen spoil blocks are concentrated by final, mid-winter dozer contouring. Thawing of these blocks results in local surface subsidence. In contrast, areas contoured in mid-winter with a scraper are stable because large blocks of frozen spoil are broken apart, spread, and compacted. This type of landscape instability is, therefore, largely equipment and seasonally controlled.

Piping appears to be a severe and long-term problem in some postmining landscapes. Development usually begins soon after contouring and may continue for several years. In some postmining landscapes, piping has only started to develop after as much as 5 years of apparent stability. It is controlled by a combination of physical and chemical conditions in the spoils.

A key factor in the development of piping features is the cracking of spoils in areas containing highly dispersive sodic material. These cracks allow access for large volumes of surface runoff to flow into the subsurface. Piping generally develops on nearly flat slopes where surface runoff is minimal and infiltration is maximized.

Piping, like the other instability problems, most commonly develops in areas contoured by dozers. Scraper-contoured areas generally are better compacted, thus providing fewer subsurface avenues for infiltration of surface water.

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<sup>1/</sup> Groenewold, G.H., and Rehm, B.W., 1980.

## Weathering Tests

Laboratory weathering and outdoor exposure tests were conducted on overburden samples from the Pumpkin Creek, Montana Study Area. The purpose of these tests was to determine which materials would break down sufficiently to allow for their possible use as planting media in revegetation of strip-mined areas.

Specimens for laboratory weathering and outdoor exposure tests were cut from core samples obtained from Drill Hole 76-101 (USBR). In addition, composite samples of crushed core from the same drill hole measuring 300 mm by 300 mm by 50 mm (12 in. by 12 in. by 2 in.) were prepared and tested.

The reason for including outdoor exposure tests was to determine if any correlation could be drawn between this type of weathering and the laboratory weathering conditions. A laboratory weathering cycle consisted of the following conditions:

1. Eight hours at 23.9°C (75°F), 100 percent relative humidity (wetting/thawing).
2. Sixteen hours (64 hours on weekends) at 37.8°C (100°F), 10 percent relative humidity (drying).
3. Eight hours at 23.9°C (75°F), 100 percent relative humidity (wetting).
4. Sixteen hours (64 hours on weekends) at -17.8°C (0°F) freezing.

The core specimens tested were approximately 50 mm (2 inches) in length. For testing and handling, each core specimen was placed on a No. 10 mesh screen in a 400-ml plastic beaker.

Laboratory weathering tests were started on December 13, 1977, and 20 laboratory weathering cycles were completed on February 10, 1978. Outdoor exposure tests commenced on December 13, 1977, and were completed on December 12, 1978. During this one-year period, the specimens were subjected to 250 mm (10 in) of precipitation.

Test results are summarized in Table 1 (Appendix B) and shown visually in Photographs 6 through 14 (Appendix B).

At the completion of the weathering tests, a percent breakdown value (%BD) was determined for the specimens. This value listed under the Remarks column in the table was derived as follows:

$$\%BD = \frac{TW - IW}{TW} (100)$$

where

TW = total specimen weight  
IW = weight of original specimen  
remaining intact after testing.

For the overburden samples from Pumpkin Creek the following materials broke down sufficiently to be considered for possible use as planting media: shale samples PC-1, PC-4, and PC-5; and siltstone sample PC-2 (See Photographs 6 and 7, Appendix B). Very little breakdown was noted for composite sample PC-7A after 20 laboratory weathering cycles (See Photograph 12, Appendix B). However, composite sample PC-7B showed considerable breakdown after 1 year of outdoor exposure (See Photograph 14, Appendix B).

With regard to correlation between laboratory and outdoor weathering conducted concurrently, the former appeared to be more severe. This was primarily due to the rather mild winter weather and low precipitation that the outdoor exposure specimens were subjected to.

### Seismicity

The Pumpkin Creek Study Area lies within a relatively stable part of North America. All of eastern Montana is within Zone 1 of the Algermisson Seismic Risk Map. In this zone distant earthquakes can cause minor damage to structures with fundamental periods greater than 1.0 second (Corresponds to intensities V and VI of the Modified Mercalli Intensity Scale of 1931).

No earthquakes of intensity V or above (Modified Mercalli) have occurred in eastern Montana during historical times.

The Yellowstone Park area is the most active seismic region within 300 miles of the Pumpkin Creek Study Area. The largest earthquake (7.1 Richter) recorded in this area occurred at Hebgen Lake, Montana, on August 17, 1959, a distance of about 280 miles from the study area. Although considerable damage occurred near the epicenter, the quake was not readily noticed in the Powder River Basin.

Several earthquakes with intensities of V to VI (Modified Mercalli) have been recorded within 150 miles of the study area. These are listed below:

<u>Date</u>	<u>Intensity (Modified Mercalli)</u>	<u>Distance from Pumpkin Creek</u>	<u>Located Near</u>
October 11, 1895	V	150 miles	Keystone, SD
November 17, 1925	V	85 miles	Bighorn, WY
November 16, 1928	V	150 miles	Custer, SD
June 26, 1966	VI	150 miles	Rapid City, SD

# COAL RESOURCES<sup>1/</sup>

## Introduction

This report was prepared as a contribution to the study of the coal mining potential of an area in the southwest part of the Coalwood Coalfield, the southeast part of the Ashland Coalfield, and the northeast part of the Birney-Broadus Coalfield in southeast Montana. The area was selected for investigation by the EMRIA (Energy Minerals Rehabilitation Inventory and Analysis) program of the U.S. Bureau of Land Management. The Pumpkin Creek Study Area was selected for evaluation of the Coalbeds A, Sawyer, and Mackin-Walker. This report summarizes information on resources and coal quality gained during the study, and is based on field observations and data from drill holes.

The Pumpkin Creek site is an area of about 94 square miles between Pumpkin Creek, a tributary of the Tongue River, and Mizpah Creek, a tributary of the Powder River (Figure 1). The site includes the Leslie Creek 7-1/2 minute topographic quadrangle and parts of Box Elder Creek, Coalwood, and Olive 7-1/2 minute topographic quadrangles.

The geology of the coalbeds was mapped by Marguerite Glenn with the assistance of Jeanette Hartman (USGS) during the summers of 1976 and 1977. Aerial photographs were used to locate outcrops and outline areas of burned beds as a supplement to field observations. Fresh coal samples, coal quality information, and coal thicknesses used in resource calculations were obtained from 12 holes drilled and cored by the Geological Survey, 10 holes cored by the Bureau of Reclamation, 11 holes (1 just outside the EMRIA site) drilled by the Montana Bureau of Mines and Geology and the U.S. Geological Survey, and from about 3 dozen previously drilled holes. J.R. Hatch sampled the coal cores for analysis. The results of the analyses are discussed by J.R. Hatch and R.H. Affolter in Appendix C.

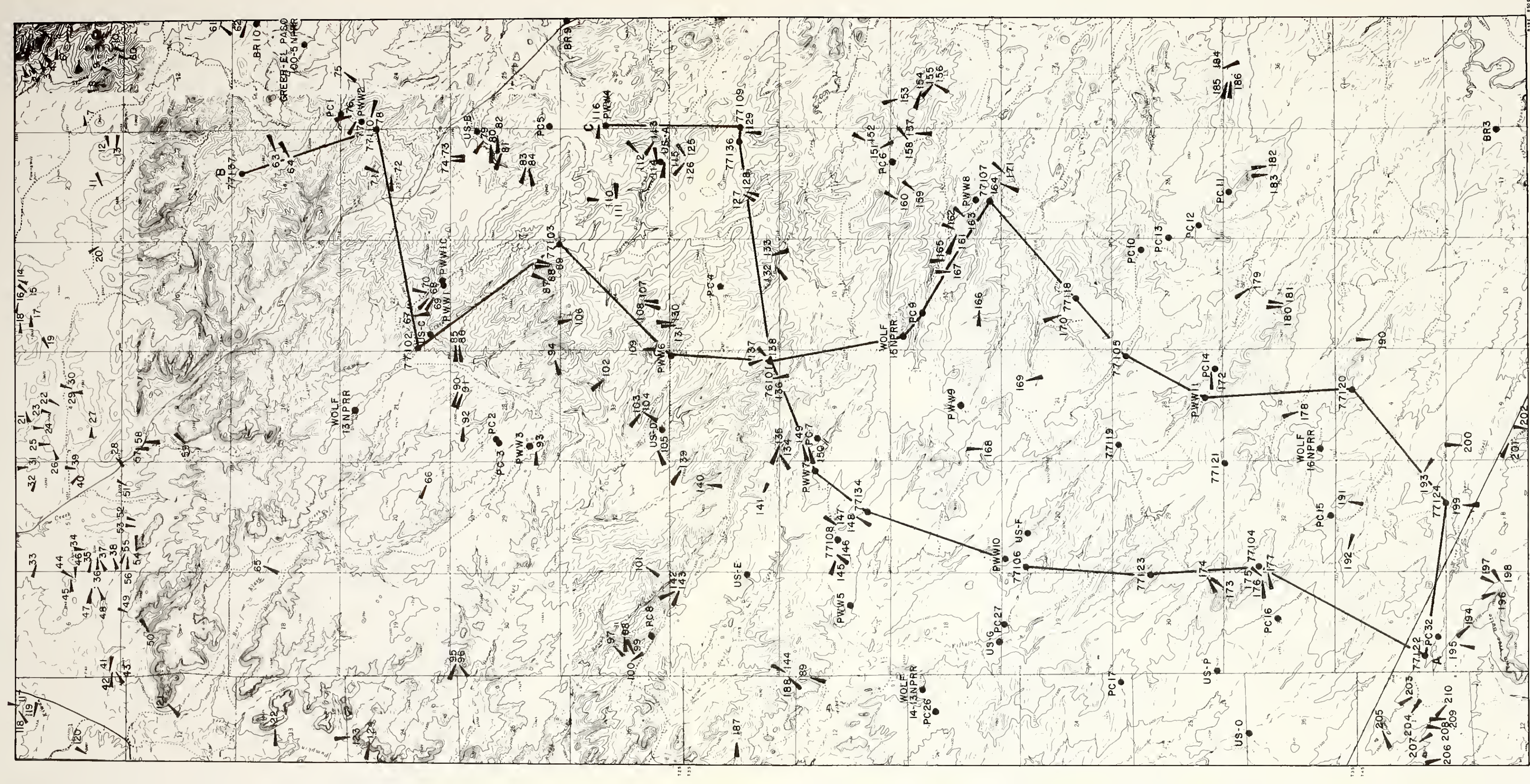
## Geologic Setting

The coalbeds in the Pumpkin Creek area are in the lower part of the Tongue River Member of the Fort Union Formation of Paleocene age. Approximately 800 feet of mudstone, siltstone, sandstone, silty limestone, and coal comprise the Tongue River Member in the study site. The top of the member is eroded and the base is not exposed. The coal and enclosing strata generally dip less than 1 degree to the west. The regional westward dip is interrupted locally by very low amplitude undulations, probably related to differential compaction of the rocks of the Tongue River Member.

Localities where the coalbeds were measured or observed on the surface, holes drilled for the EMRIA study, holes previously drilled from which coal thickness data were used, and lines of drill hole sections are shown on Plate 16.

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<sup>1/</sup> The following supplements are included for reference in Appendix C: (1) a general discussion of coal type, rank, etc.; and (2) a technical paper describing chemical analyses of lignite from the Tongue River Member of the Fort Union Formation, Pumpkin Creek Study Area.



Base from U.S. Geological Survey Box Elder Creek,  
Leslie Creek, Coolwood, and Olive Quadrangle maps

CONTOUR INTERVAL 20 FEET



## LOCALITY MAP OF THE PUMPKIN CREEK EMRIA STUDY SITE

BOX ELDER CREEK, LESLIE CREEK, COALWOOD, AND  
OLIVE QUADRANGLES, POWDER RIVER COUNTY MONTANA

BY  
MARGUERITE GLENN  
1978

## EXPLANATION

LOCALITY AT WHICH COAL WAS MEASURED OR OBSERVED--Number shown near point of triangle. Coal beds and their thicknesses are shown on table 2

DRILL HOLE--Number shown above  
Holes drilled for the EXRIA study are shown as follows:  
PMW-77411. Holes drilled by U.S. Geological Survey  
7601. 77102--77110. Holes drilled by the U.S. Bureau of Reclamation  
77118--77137. Holes drilled by Montana Bureau of Mines and Geology  
and U.S. Geological Survey

Previously drilled holes from which data (Macrone, Blumert, and Vagelin, 1970) were obtained by geophysical and drillers' logs were used as shown as follows:

US-A-M-S-C. US-0, and US-P. Holes drilled by U.S. Geological Survey BRJ, BR9, PGI-PC17, PC26, PC27, PC32, and PC33. Holes drilled by Northern Pacific Railroad and Montana Bureau of Mines and Geology.

Greenland. Holes 100-5 NPB8, 101-5 NPB8, 102-5 NPB8, 103-5 NPB8, 104-5 NPB8, 105-5 NPB8, 106-5 NPB8, 107-5 NPB8, 108-5 NPB8, 109-5 NPB8, 110-5 NPB8, 111-5 NPB8, 112-5 NPB8, 113-5 NPB8, 114-5 NPB8, 115-5 NPB8, 116-5 NPB8, 117-5 NPB8, 118-5 NPB8, 119-5 NPB8, 120-5 NPB8, 121-5 NPB8, 122-5 NPB8, 123-5 NPB8, 124-5 NPB8, 125-5 NPB8, 126-5 NPB8, 127-5 NPB8, 128-5 NPB8, 129-5 NPB8, 130-5 NPB8, 131-5 NPB8, 132-5 NPB8, 133-5 NPB8, 134-5 NPB8, 135-5 NPB8, 136-5 NPB8, 137-5 NPB8, 138-5 NPB8, 139-5 NPB8, 140-5 NPB8, 141-5 NPB8, 142-5 NPB8, 143-5 NPB8, 144-5 NPB8, 145-5 NPB8, 146-5 NPB8, 147-5 NPB8, 148-5 NPB8, 149-5 NPB8, 150-5 NPB8, 151-5 NPB8, 152-5 NPB8, 153-5 NPB8, 154-5 NPB8, 155-5 NPB8, 156-5 NPB8, 157-5 NPB8, 158-5 NPB8, 159-5 NPB8, 160-5 NPB8, 161-5 NPB8, 162-5 NPB8, 163-5 NPB8, 164-5 NPB8, 165-5 NPB8, 166-5 NPB8, 167-5 NPB8, 168-5 NPB8, 169-5 NPB8, 170-5 NPB8, 171-5 NPB8, 172-5 NPB8, 173-5 NPB8, 174-5 NPB8, 175-5 NPB8, 176-5 NPB8, 177-5 NPB8, 178-5 NPB8, 179-5 NPB8, 180-5 NPB8, 181-5 NPB8, 182-5 NPB8, 183-5 NPB8, 184-5 NPB8, 185-5 NPB8, 186-5 NPB8, 187-5 NPB8, 188-5 NPB8, 189-5 NPB8, 190-5 NPB8, 191-5 NPB8, 192-5 NPB8, 193-5 NPB8, 194-5 NPB8, 195-5 NPB8, 196-5 NPB8, 197-5 NPB8, 198-5 NPB8, 199-5 NPB8, 200-5 NPB8, 201-5 NPB8, 202-5 NPB8, 203-5 NPB8, 204-5 NPB8, 205-5 NPB8, 206-5 NPB8, 207-5 NPB8, 208-5 NPB8, 209-5 NPB8, 210-5 NPB8, 211-5 NPB8, 212-5 NPB8, 213-5 NPB8, 214-5 NPB8, 215-5 NPB8, 216-5 NPB8, 217-5 NPB8, 218-5 NPB8, 219-5 NPB8, 220-5 NPB8, 221-5 NPB8, 222-5 NPB8, 223-5 NPB8, 224-5 NPB8, 225-5 NPB8, 226-5 NPB8, 227-5 NPB8, 228-5 NPB8, 229-5 NPB8, 230-5 NPB8, 231-5 NPB8, 232-5 NPB8, 233-5 NPB8, 234-5 NPB8, 235-5 NPB8, 236-5 NPB8, 237-5 NPB8, 238-5 NPB8, 239-5 NPB8, 240-5 NPB8, 241-5 NPB8, 242-5 NPB8, 243-5 NPB8, 244-5 NPB8, 245-5 NPB8, 246-5 NPB8, 247-5 NPB8, 248-5 NPB8, 249-5 NPB8, 250-5 NPB8, 251-5 NPB8, 252-5 NPB8, 253-5 NPB8, 254-5 NPB8, 255-5 NPB8, 256-5 NPB8, 257-5 NPB8, 258-5 NPB8, 259-5 NPB8, 260-5 NPB8, 261-5 NPB8, 262-5 NPB8, 263-5 NPB8, 264-5 NPB8, 265-5 NPB8, 266-5 NPB8, 267-5 NPB8, 268-5 NPB8, 269-5 NPB8, 270-5 NPB8, 271-5 NPB8, 272-5 NPB8, 273-5 NPB8, 274-5 NPB8, 275-5 NPB8, 276-5 NPB8, 277-5 NPB8, 278-5 NPB8, 279-5 NPB8, 280-5 NPB8, 281-5 NPB8, 282-5 NPB8, 283-5 NPB8, 284-5 NPB8, 285-5 NPB8, 286-5 NPB8, 287-5 NPB8, 288-5 NPB8, 289-5 NPB8, 290-5 NPB8, 291-5 NPB8, 292-5 NPB8, 293-5 NPB8, 294-5 NPB8, 295-5 NPB8, 296-5 NPB8, 297-5 NPB8, 298-5 NPB8, 299-5 NPB8, 300-5 NPB8, 301-5 NPB8, 302-5 NPB8, 303-5 NPB8, 304-5 NPB8, 305-5 NPB8, 306-5 NPB8, 307-5 NPB8, 308-5 NPB8, 309-5 NPB8, 310-5 NPB8, 311-5 NPB8, 312-5 NPB8, 313-5 NPB8, 314-5 NPB8, 315-5 NPB8, 316-5 NPB8, 317-5 NPB8, 318-5 NPB8, 319-5 NPB8, 320-5 NPB8, 321-5 NPB8, 322-5 NPB8, 323-5 NPB8, 324-5 NPB8, 325-5 NPB8, 326-5 NPB8, 327-5 NPB8, 328-5 NPB8, 329-5 NPB8, 330-5 NPB8, 331-5 NPB8, 332-5 NPB8, 333-5 NPB8, 334-5 NPB8, 335-5 NPB8, 336-5 NPB8, 337-5 NPB8, 338-5 NPB8, 339-5 NPB8, 340-5 NPB8, 341-5 NPB8, 342-5 NPB8, 343-5 NPB8, 344-5 NPB8, 345-5 NPB8, 346-5 NPB8, 347-5 NPB8, 348-5 NPB8, 349-5 NPB8, 350-5 NPB8, 351-5 NPB8, 352-5 NPB8, 353-5 NPB8, 354-5 NPB8, 355-5 NPB8, 356-5 NPB8, 357-5 NPB8, 358-5 NPB8, 359-5 NPB8, 360-5 NPB8, 361-5 NPB8, 362-5 NPB8, 363-5 NPB8, 364-5 NPB8, 365-5 NPB8, 366-5 NPB8, 367-5 NPB8, 368-5 NPB8, 369-5 NPB8, 370-5 NPB8, 371-5 NPB8, 372-5 NPB8, 373-5 NPB8, 374-5 NPB8, 375-5 NPB8, 376-5 NPB8, 377-5 NPB8, 378-5 NPB8, 379-5 NPB8, 380-5 NPB8, 381-5 NPB8, 382-5 NPB8, 383-5 NPB8, 384-5 NPB8, 385-5 NPB8, 386-5 NPB8, 387-5 NPB8, 388-5 NPB8, 389-5 NPB8, 390-5 NPB8, 391-5 NPB8, 392-5 NPB8, 393-5 NPB8, 394-5 NPB8, 395-5 NPB8, 396-5 NPB8, 397-5 NPB8, 398-5 NPB8, 399-5 NPB8, 400-5 NPB8, 401-5 NPB8, 402-5 NPB8, 403-5 NPB8, 404-5 NPB8, 405-5 NPB8, 406-5 NPB8, 407-5 NPB8, 408-5 NPB8, 409-5 NPB8, 410-5 NPB8, 411-5 NPB8, 412-5 NPB8, 413-5 NPB8, 414-5 NPB8, 415-5 NPB8, 416-5 NPB8, 417-5 NPB8, 418-5 NPB8, 419-5 NPB8, 420-5 NPB8, 421-5 NPB8, 422-5 NPB8, 423-5 NPB8, 424-5 NPB8, 425-5 NPB8, 426-5 NPB8, 427-5 NPB8, 428-5 NPB8, 429-5 NPB8, 430-5 NPB8, 431-5 NPB8, 432-5 NPB8, 433-5 NPB8, 434-5 NPB8, 435-5 NPB8, 436-5 NPB8, 437-5 NPB8, 438-5 NPB8, 439-5 NPB8, 440-5 NPB8, 441-5 NPB8, 442-5 NPB8, 443-5 NPB8, 444-5 NPB8, 445-5 NPB8, 446-5 NPB8, 447-5 NPB8, 448-5 NPB8, 449-5 NPB8, 450-5 NPB8, 451-5 NPB8, 452-5 NPB8, 453-5 NPB8, 454-5 NPB8, 455-5 NPB8, 456-5 NPB8, 457-5 NPB8, 458-5 NPB8, 459-5 NPB8, 460-5 NPB8, 461-5 NPB8, 462-5 NPB8, 463-5 NPB8, 464-5 NPB8, 465-5 NPB8, 466-5 NPB8, 467-5 NPB8, 468-5 NPB8, 469-5 NPB8, 470-5 NPB8, 471-5 NPB8, 472-5 NPB8, 473-5 NPB8, 474-5 NPB8, 475-5 NPB8, 476-5 NPB8, 477-5 NPB8, 478-5 NPB8, 479-5 NPB8, 480-5 NPB8, 481-5 NPB8, 482-5 NPB8, 483-5 NPB8, 484-5 NPB8, 485-5 NPB8, 486-5 NPB8, 487-5 NPB8, 488-5 NPB8, 489-5 NPB8, 490-5 NPB8, 491-5 NPB8, 492-5 NPB8, 493-5 NPB8, 494-5 NPB8, 495-5 NPB8, 496-5 NPB8,

NOTES DRILLED IN EX-

LINES OF SECTIONS A-B AND A-C

## REFERENCE

Mason, R.E., Blumer, J.W., and Wegelin, L.A., 1973. Quality and reserves of stripable coal, selected deposits, southeastern Montana: Montana Bur. Mines and Geology Bull. 91 135 p.

REDRAFTED BY:  
BUREAU OF RECLAMATION  
BILLINGS, MONTANA



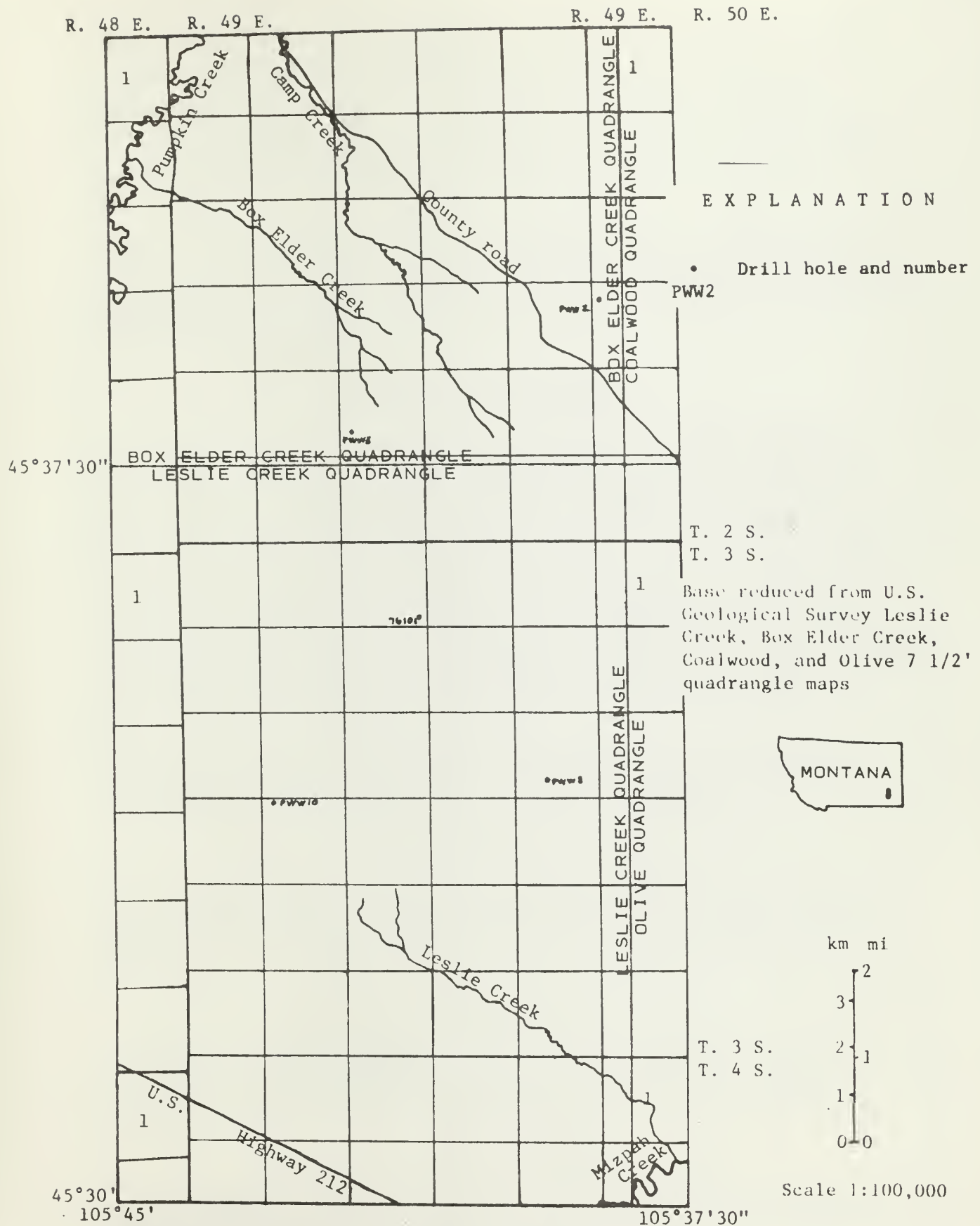


Figure 1.--Index map of the Pumpkin Creek EMRIA study site, Powder River County, Montana, showing drill holes from which coal samples were taken



The localities where coal was measured or observed on the surface, names of beds measured, and coal thicknesses are shown in geographic order in Table 2, Appendix C. Outcrops and thickness of coalbeds, areas of burned beds, alluvial and terrace deposits, locations of abandoned mines, and some faults are shown on Plate 17. Structure of the Coalbeds A, Sawyer, and Mackin-Walker and the areas of measured, indicated, and inferred resources for each bed are shown on Plates 18, 19, and 20, Appendix C.

Sections of the coalbeds in all the holes drilled for the EMRIA study are shown on Plate 21, Appendix C. Lines of sections showing thicknesses of coalbeds, thinning of the Mackin-Walker bed to the south, and southward thickening of the parting between the Sawyer and A Coalbeds are shown on Plates 22 and 23, Appendix C.

### Description of the Coalbeds

The names and relative stratigraphic positions of the coal (lignite) beds in the study site are shown in Figure 2 and Plate 17. The names are those used previously by other geologists mapping in the area. The Allen, Broadus, Flowers-Goodale, Knobloch, A, Sawyer, Mackin-Walker, Stump, and X beds as used in Tps. 2 and 3 S., R. 49 E., are taken from Bryson (1951) as he mapped these beds in the Coalwood Coalfield. Along the west edge of the area in Tps. 2 and 3 S., R. 48 E., the names Knobloch, A, and Sawyer had been used previously by Bass (1932) in the Ashland Coalfield. The name Sawyer was first used by Dobbin (1929, p. 28, 49-50) in the Forsyth Field. The name Pawnee is from a report by Warren (1959) as he mapped the bed in T. 4 S., R. 49 E., of the Birney-Broadus Coalfield. Brown and others (1954, p. 186-190) and Matson, and other (1973) also have discussed the coalbeds in this area.

Structure of the coalbeds is shown on Plates 18, 19, and 20, Appendix C. Thicknesses of coal, partings, and coalbed pinch outs are shown in the drill hole sections on Plates 21, 22, and 23, Appendix C.

#### Local Bed L1 Below the Allen Bed

A local (L1) coalbed outcrops in sec. 31, T. 1 S., R. 49 E., where it is 2.7 feet thick (.8 m). It extends also into sec. 6, T. 2 S., R. 49 E. (Plate 17). It is about 300 feet (30.5 m) below the Flowers-Goodale Coalbed.

#### Allen Bed

The Allen Coalbed outcrops in T. 1 S., R. 49 E., and extends into the north part of T. 2 S., R. 49 E. (Plate 17). It is 1.2-2.9 feet (0.7-0.9 m) thick and is about 40 feet (12.2 m) below the Flowers-Goodale Coalbed.

#### Local Bed L2 Below the Flowers-Goodale Bed

A local coalbed (L2) outcrops about 15 feet (4.6 m) below the Flowers-Goodale, locally, in the northwest part of T. 2 S., R. 49 E. (Plate 17). It is 1.7-3.7 feet (0.5-1.1 m) thick.

## Flowers-Goodale Beds

The Flowers-Goodale Coalbed outcrops in the south part of T. 1 S., R. 49 E., the north part of T. 2 S., R. 49 E., and in T. 2 S., R. 48 E. It ranges in thickness from less than 2 feet (0.6 m) to about 4 feet (1.2 m) and locally in sec. 5, T. 2 S., R. 49 E., it splits into two beds of similar thickness (Plate 17). The Flowers-Goodale was considered by Bryson (1951, p. 75) to be the equivalent of the Broadus Coalbed, which is about 135 feet (41 m) above the base of the Tongue River Member of the Fort Union Formation. The name Broadus is used in this study to refer to a thicker coalbed reported in drill holes in the south and east parts of the area, and the name Flowers-Goodale is used for the thinner coalbed exposed on the surface in the north.

## Knobloch Bed

The Knobloch Coalbed is about 60 feet (18 m) above the Flowers-Goodale and about 120-140 feet (38-43 m) below the Sawyer in the north part of the area. It ranges from 2 to 12 feet (0.6-3.6 m) in thickness, and locally occurs as two beds of similar thickness about 30-40 feet (9-12 m) apart. It outcrops in the north part of the study site and is reported in drill holes throughout the area (Plate 17).

## Sawyer and A Beds

The main coalbed of the study site is the generally 30-foot-thick Sawyer. Although the Sawyer has burned extensively along the outcrop edges, large unburned resources of it underlie the south half of T. 2 S., R. 49 E., most of T. 3 S., R. 49 E., and most of Tps. 3 and 4 S., R. 48 E., and T. 4 S., R. 49 E. (Plate 17).

In the middle of the Sawyer Coalbed is a persistent shale parting, 0.5-2 feet (0.15-0.6 m) thick that thickens abruptly in the southern third of T. 3 S. and continues southward into T. 4 S. where it becomes as much as 50 feet (15 m) thick (Plate 17 and Plates 21, 22, and 23, Appendix C).

The name A is used for the lower split of the Sawyer where the parting between the two coals is more than 2 feet (0.6 m) thick (Plate 17 and Plates 21, 22, and 23, Appendix C). In sec. 4, T. 4 S., R. 49 E., Coalbed A is split into two coalbeds (Plate 17 and Plate 22, Appendix C). In sec. 33, T. 1 S., R. 49 E., Coalbed A is 3.3-4.5 feet (1-1.4 m) thick and lies about 40 feet (12 m) below the Sawyer. In the north part of T. 2 S., R. 49 E., however, Coalbed A and the Sawyer Coalbed both are burned and so difficult to distinguish that, in most places, they are mapped together. In the southern part of the study area, Coalbed A ranges from 9 to 16 feet (2.7-4.9 m) in thickness and the Sawyer from 12 to 20 feet (3.7-6.1 m).

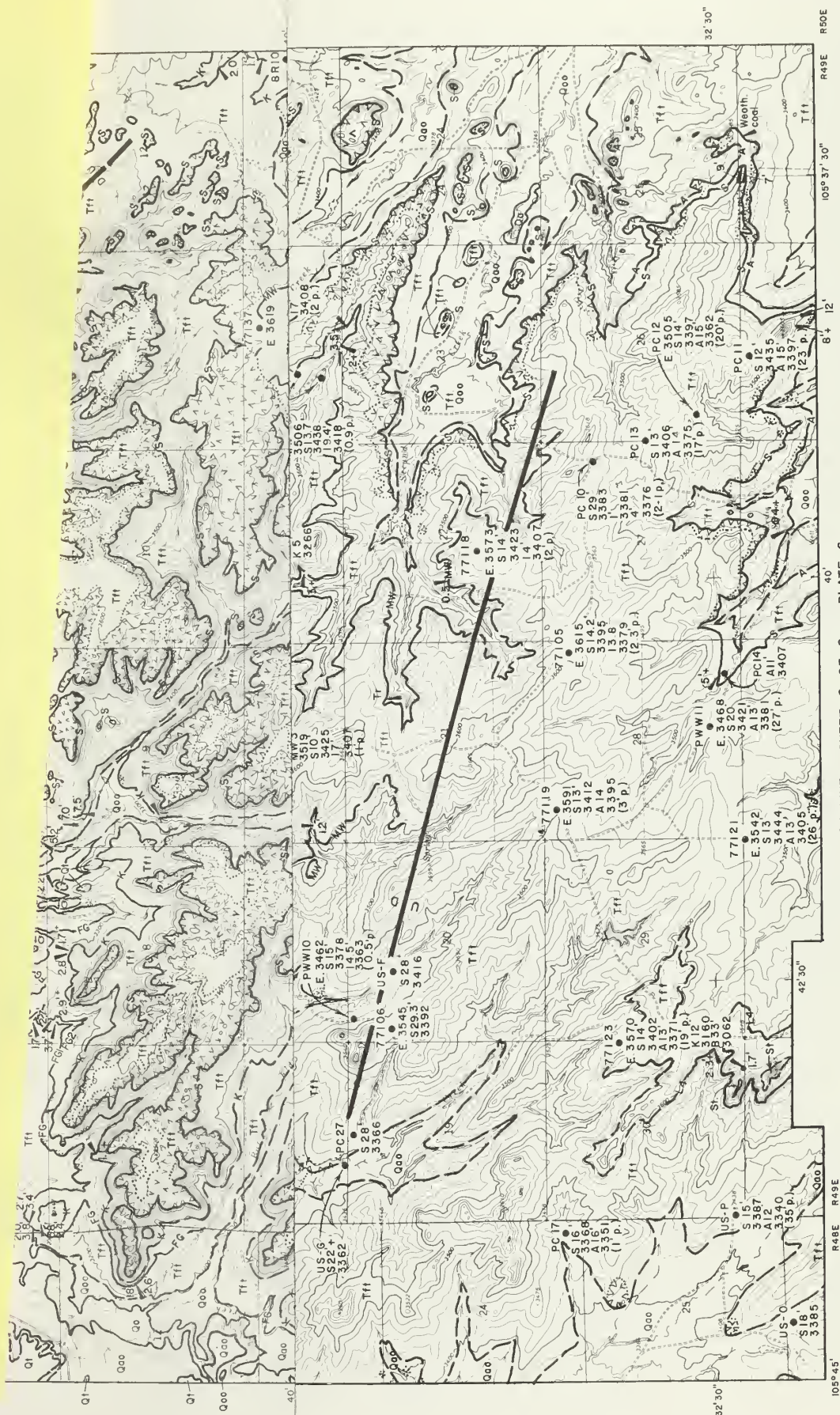
## Local Bed L3 Above the Sawyer Bed

In the south part of T. 3 S., R. 49 E., and the north part of T. 4 S., R. 49 E., a local coal (L3) is 50-75 feet (15-23 m) above the Sawyer (Plate 17). The thickness of the coal is 1-3 feet.

DEF  
UNIT

107  
T1S  
T2E

Q1



MATCH LINE - SHEET 2 OF 2 - PLATE 6

40'

105°45'

R48E R49E

42°30"

40'

40'

8+ 12'

105°37'30"

R49E R50E

32°30"

32°30"

## Flowers-Goodale Beds

The Flowers-Goodale Coalbed outcrops in the south part of T. 1 S., R. 49 E., the north part of T. 2 S., R. 49 E., and in T. 2 S., R. 48 E. It ranges in thickness from less than 2 feet (0.6 m) to about 4 feet (1.2 m) and locally in sec. 5, T. 2 S., R. 49 E., it splits into two beds of similar thickness (Plate 17). The Flowers-Goodale was considered by Bryson (1951, p. 75) to be the equivalent of the Broadus Coalbed, which is about 135 feet (41 m) above the base of the Tongue River Member of the Fort Union Formation. The name Broadus is used in this study to refer to a thicker coalbed reported in drill holes in the south and east parts of the area, and the name Flowers-Goodale is used for the thinner coalbed exposed on the surface in the north.

## Knobloch Bed

The Knobloch Coalbed is about 60 feet (18 m) above the Flowers-Goodale and about 120-140 feet (38-43 m) below the Sawyer in the north part of the area. It ranges from 2 to 12 feet (0.6-3.6 m) in thickness, and locally occurs as two beds of similar thickness about 30-40 feet (9-12 m) apart. It outcrops in the north part of the study site and is reported in drill holes throughout the area (Plate 17).

## Sawyer and A Beds

The main coalbed of the study site is the generally 30-foot-thick Sawyer. Although the Sawyer has burned extensively along the outcrop edges, large unburned resources of it underlie the south half of T. 2 S., R. 49 E., most of T. 3 S., R. 49 E., and most of Tps. 3 and 4 S., R. 48 E., and T. 4 S., R. 49 E. (Plate 17).

In the middle of the Sawyer Coalbed is a persistent shale parting, 0.5-2 feet (0.15-0.6 m) thick that thickens abruptly in the southern third of T. 3 S. and continues southward into T. 4 S. where it becomes as much as 50 feet (15 m) thick (Plate 17 and Plates 21, 22, and 23, Appendix C).

The name A is used for the lower split of the Sawyer where the parting between the two coals is more than 2 feet (0.6 m) thick (Plate 17 and Plates 21, 22, and 23, Appendix C). In sec. 4, T. 4 S., R. 49 E., Coalbed A is split into two coalbeds (Plate 17 and Plate 22, Appendix C). In sec. 33, T. 1 S., R. 49 E., Coalbed A is 3.3-4.5 feet (1-1.4 m) thick and lies about 40 feet (12 m) below the Sawyer. In the north part of T. 2 S., R. 49 E., however, Coalbed A and the Sawyer Coalbed both are burned and so difficult to distinguish that, in most places, they are mapped together. In the southern part of the study area, Coalbed A ranges from 9 to 16 feet (2.7-4.9 m) in thickness and the Sawyer from 12 to 20 feet (3.7-6.1 m).

## Local Bed L3 Above the Sawyer Bed

In the south part of T. 3 S., R. 49 E., and the north part of T. 4 S., R. 49 E., a local coal (L3) is 50-75 feet (15-23 m) above the Sawyer (Plate 17). The thickness of the coal is 1-3 feet.





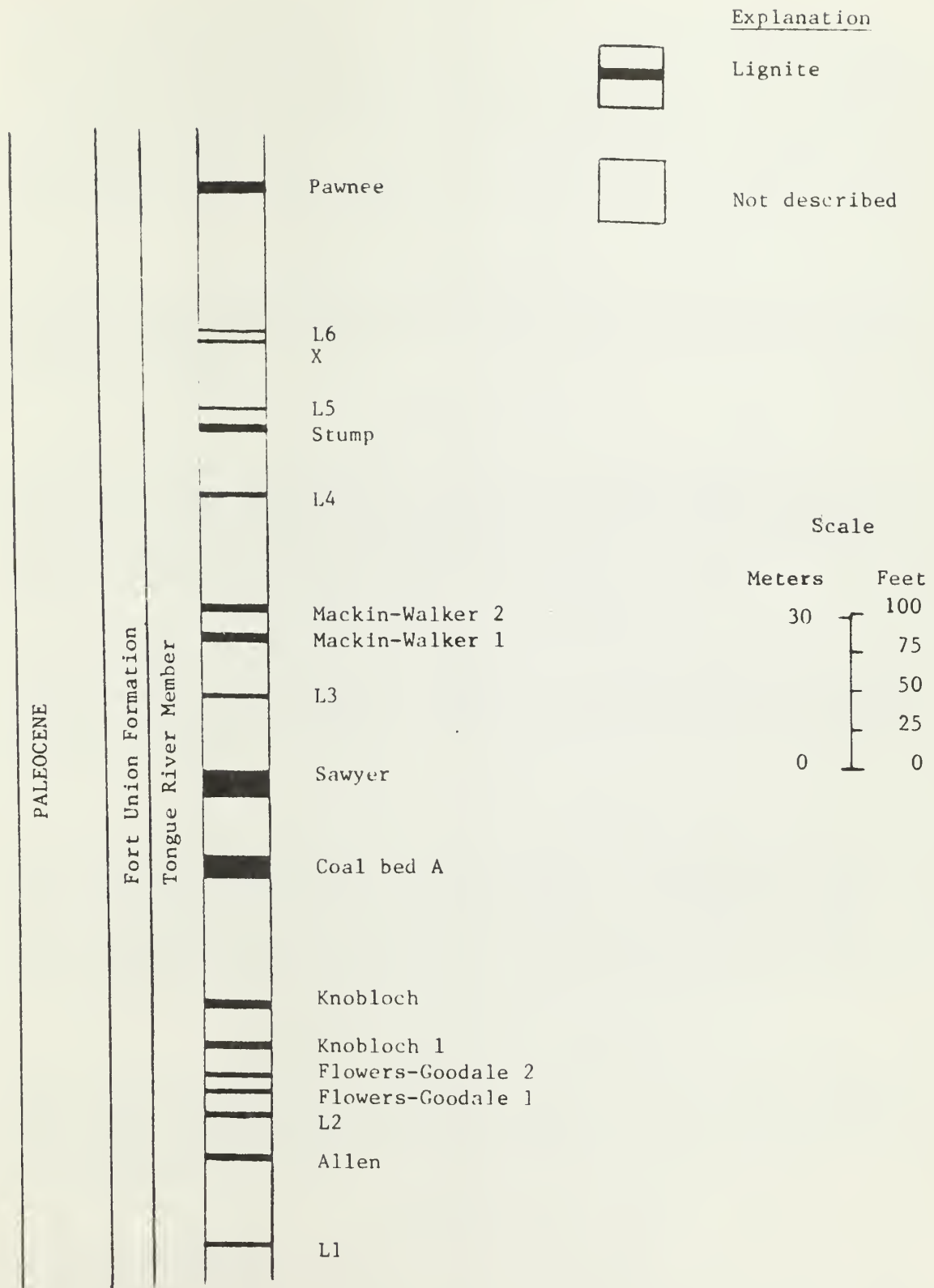


Figure 2.-- Generalized section showing relative stratigraphic positions of lignite beds in Pumpkin Creek EMRIA study site, southeastern Montana.



## Mackin-Walker Beds

The next higher coalbed is the Mackin-Walker, which lies 80-120 feet (24-38 m) above the base of the Sawyer and extends over the north half of T. 3 S., R. 49 E., and the south half of T. 2 S., R. 49 E. (Plate 17). It is 9.7 feet (3 m) thick at an abandoned mine in sec. 35, T. 2 S., R. 49 E., but thins in all directions from this point. In the southwest part of T. 2 S., R. 49 E., it occurs as two beds 30-40 feet apart. It was named for a mine once worked in sec. 28, T. 2 S., R. 49 E., where it was 6.2 feet (1.9 m) thick (Plate 17; Bryson, 1951, p. 76, 84).

### Local Bed L4 Above the Sawyer Bed

A local coalbed (L4) is 185-200 feet (56-61 m) above the Sawyer in the southwest part of T. 3 S., R. 49 E. (Plate 17). It is about 1-2.5 feet (0.3-0.8 m) thick.

### Stump Bed

The Stump Coalbed is 250-300 feet (73-92 m) above the Sawyer (Plate 17). It is usually 2-3 feet (0.6-0.9 m) thick and somewhat shaly, but it is distinctive because nearly everywhere it contains silicified, partly carbonized tree stumps in growing position. It was correlated tentatively with the C bed in the Ashland field (Bryson, 1951, P. 76a).

### Local Bed L5 Below the Pawnee Bed

In the southwest corner of the study site, a local coalbed (L5) occurs about 250 feet (76 m) above the Sawyer and 120-130 feet (38-40 m) below the Pawnee (Plate 17). It is 2-3 feet (0.6-0.9 m) thick and may equal the Stump Coalbed.

### X Bed

The X bed is about 55-80 feet (17-24 m) above the Stump Coalbed and about 300 feet (91 m) above the Sawyer (Plate 17). Bed X has burned to form a 20-foot-thick (6.1-meter-thick) clinker. The clinker remains only in sec. 34, T. 2 S., R. 49 E., the highest part of the divide between Pumpkin Creek and Mizpah Creek. Bryson tentatively correlated it with the X Bed in the Ashland field (1951, p. 77).

### Local Bed L6 Below the Pawnee Bed

Another local coalbed, L6, 2-3 feet (0.6-0.9 m) thick, occurs locally in the southwest corner of the study area (Plate 17). It is about 300 feet (91 m) above the Sawyer and 70-90 feet (21-27 m) below the Pawnee on Two Tree Butte.

### Pawnee Bed

The highest coalbed in the study site is the Pawnee. It is represented by the clinker on Two Tree Butte (Plate 17). No unburned sections could be measured.

## Estimation and Classification of Coal Resources

Coal resource estimates have been prepared for the Coalbeds A, Sawyer, and Mackin-Walker in the vicinity of the Pumpkin Creek EMRIA Study Site as summarized by Tables 3 and 4 using standard procedures, definitions, and criteria established by the U.S. Geological Survey and U.S. Bureau of Mines for making coal resource appraisals in the United States. The term "coal resources" as used in this report means the estimated quantity of coal in the ground in such form that economic extraction is currently or potentially feasible.

The resources in the study area are classed as measured, indicated, and inferred according to the degree of geologic assurance of the estimate. The areas of the various classified resources are shown on the structure and resources map for each coalbed evaluated (Plates 18, 19, and 20, Appendix C).

### Measured Resources

Resources are computed from dimensions revealed in outcrops, trenches, mine workings, and drill holes. The points of observation and measurement are so closely spaced and the thickness and extent of coals are so well defined that the tonnage is judged to be accurate within 20 percent of true tonnage. Although the spacing of the points of observation necessary to demonstrate continuity of the coal differs from region to region according to the character of the coalbeds, the points of observation are no greater than 1/2 mile (0.8 km) apart. Measured coal is projected to extend as a 1/4 mile (0.4 km) wide belt from the outcrop or points of observation or measurement.

### Indicated Resources

Resources are computed partly from specific measurements and partly from projections of visible data for a reasonable distance on the basis of geologic evidence. The points of observation are 1/2 (0.8 km) to 1-1/2 miles (2.4 km) apart. Indicated coal is projected to extend as a 1/2 mile (0.8 km) wide belt that lies more than 1/4 mile (0.4 km) from the outcrop or points of observation or measurement.

### Inferred Resources

Quantitative estimates are based largely on broad knowledge of the geologic character of the bed or region, because few measurements of bed thickness are available. The estimates are based primarily on an assumed continuation from measured and indicated coal for which geologic evidence exists. The points of observation are 1-1/2 (2.4 km) to 6 miles (9.6 km) apart. Inferred coal is projected to extend as a 2-1/4 mile (3.6 km) wide belt that lies more than 3/4 mile (1.2 km) from the outcrop or points of observation or measurement.

Table 3.--Measured, indicated, and inferred resources of lignite in the Tongue River Member of the Paleocene Fort Union Formation in beds more than 5 feet (1.5 m) thick, under less than 1,000 feet (305 m) of overburden, as of January 1, 1978, based on measurements at the outcrop and subsurface data.

[In thousands of short tons (1 short ton = 0.9078 metric tons); totals are rounded. The coal is assumed to weigh 1,750 short tons per acre foot (1.3 metric tons/m<sup>3</sup>). One foot = 0.3 meter. Leaders (----) indicate no data]

Location		Measured		Indicated		Inferred		Totals
Township South	Range East	Thickness of coal in feet		Thickness of coal in feet		Thickness of coal in feet		
		5-10	>10	5-10	>10	5-10	>10	
Mackin-Walker bed								
2	49	20,220	-----	6,380	-----	-----	-----	26,600
3	49	4,400	-----	3,400	-----	-----	-----	7,800
Totals		24,620	-----	9,780	-----	-----	-----	34,400
Sawyer bed								
2	48	-----	10,320	-----	-----	-----	-----	10,320
2	49	-----	274,950	-----	143,500	-----	4,510	422,960
3	48	-----	34,920	-----	63,100	-----	730	98,750
3	49	580	297,600	-----	373,880	-----	760	672,820
4	48	-----	620	-----	88,200	-----	6,100	94,920
4	49	-----	22,050	-----	35,050	-----	80	57,180
Totals		580	640,460	-----	703,730	-----	12,180	1,356,950
Coal bed A								
3	48	-----	1,570	-----	18,790	-----	750	21,110
3	49	-----	40,780	-----	54,970	-----	-----	95,750
4	48	-----	430	-----	9,910	-----	6,500	16,840
4	49	2,210	19,120	1,960	31,330	120	3,220	57,960
Totals		2,210	61,900	1,960	115,000	120	10,470	191,660
Grand totals		27,410	702,360	11,740	818,730	120	22,650	1,583,010



Table 4.--Measured, indicated, and inferred resources of lignite in the Tongue River Member of Paleocene Fort Union Formation, possibly recoverable by surface mining methods, in beds more than 5 feet (1.5 m) thick, under less than 200 feet (61 m) of overburden, as of January 1, 1978.

[In thousands of short tons (1 short ton = 0.9078 metric tons); totals are rounded. The coal is assumed to weigh 1,750 short tons per acre foot (1.3 metric tons/m<sup>3</sup>); these resources are included in table 1. Leaders (----) indicate no data]

Location		Measured		Indicated		Inferred	
Township	Range East	Thickness of coal in feet		Thickness of coal in feet		Thickness of coal in feet	
South		5-10	>10	5-10	>10	5-10	>10
Mackin-Walker bed							
2	49	20,220	-----	6,310	-----	-----	26,530
3	49	4,400	-----	3,400	-----	-----	7,800
Totals		24,620	-----	9,710	-----	-----	34,330
Sawyer bed							
2	48	-----	10,320	-----	-----	-----	10,320
2	49	-----	273,900	-----	127,800	4,510	406,210
3	48	-----	34,920	-----	63,100	730	98,750
3	49	580	286,110	-----	339,780	760	627,230
4	48	-----	-----	-----	7,700	470	8,170
4	49	-----	18,080	-----	24,900	80	43,060
Totals		580	623,330	-----	563,280	6,550	1,193,740
Coal bed A							
3	48	-----	1,570	-----	17,900	680	20,150
3	49	-----	39,740	-----	45,110	-----	84,850
4	48	-----	-----	-----	290	-----	290
4	49	2,150	16,580	1,650	15,800	120	36,540
Totals		2,150	57,890	1,650	79,100	920	141,830
Grand totals		27,350	681,220	11,360	642,380	120	1,369,900



All of the estimated resources in beds thicker than 5 feet (1.5 m) and at depths of 1000 feet (305 m) or less fall into a category called reserve base, which is defined as that portion of the identified coal resource from which reserves are calculated. Reserves are that portion of the identified coal resource that can be economically mined at the time of determination. The reserve is derived by applying a recovery factor to that component of the identified coal resource designated as the reserve base. On a national basis, the estimated recovery factor for the total reserve base is 50 percent. More precise recovery factors can be computed by determining the total coal in place and the total coal recoverable in any specific locale.

#### Characteristics Used in Resource Evaluation

The coal characteristics that are commonly used in classifying coal resources are the rank, grade, and weight of the coal; the thickness of the coalbeds; and the thickness of the overburden. Rank and grade are discussed in Appendix C.

##### Weight

The weight of the coal ranges considerably with differences in rank and ash content. In areas such as Pumpkin Creek, where true specific gravities of the coal have not been determined, an average specific gravity value based on many determinations in other areas is used to express the weight of the coal for resource calculations. The average weight of lignite is taken as 1750 tons per acre-foot - a specific gravity of 1.29.

##### Thickness of Beds

Because of the important relationship of coalbed thickness to utilization potential, most coal resource estimates prepared by the U.S. Geological Survey are tabulated according to three thickness categories. Because the coal evaluated in this report is so close to the subbituminous-lignite division of rank, the thickness categories used are intermediate - 5 to 10 feet (1.5 to 3 m), and thick - more than 10 feet (3 m). Resources in beds thinner than 5 feet were not estimated. About 2.5 percent of the estimated resources of the study site is in the intermediate category and about 97.5 percent is in the thick category. By way of comparison, Averitt (1975, Fig. 5 and p. 37) showed the distribution of the estimated resources of 21 States as 25 percent in the intermediate category and 33 percent in the thick category.

##### Thickness of Overburden

All of the estimated lignite resources in the Pumpkin Creek EMRIA site are overlain by 1,000 feet (305 m) or less of overburden (Table 3). Resources with less than 200 feet of overburden are shown on Table 4. No resources were calculated for coalbeds below Coalbed A.

### Summary of Resources

Total estimated identified original resources in the Pumpkin Creek EMRIA site are 1,583,010,000 short tons (1,437,056,478 metric tons). The coalbed thickness class of 5-10 feet (1.5-3 m) contains 39,270,000 short tons (1,402,950,172 metric tons) of estimated resources. Maximum measured thickness of the Sawyer Coalbed is 34 feet, split by a 0.9-foot (0.3 m) parting near the middle (Plate 21, Appendix C, hole 77-107).

The estimated resources presented in this report are original resources, that is, resources in the ground before the beginning of mining operations.

## OVERBURDEN - SOIL AND BEDROCK

### Principal Soil Bodies

Soils of the Pumpkin Creek Study Area can be grouped into three major categories based on their parent material and landform position. These are: (1) Residual soils developing over weathered shale or sandstone which occupy ridges, buttes, and gentle to steep sideslopes, (2) transported (alluvial/colluvial) soils forming over mixed deposits of soil material and rock fragments on fans, footslopes, and in swales, and (3) alluvial valley floor soils developing over deep water-lain deposits on nearly level bottomlands adjacent to major tributary drainages. Short and mid-grass vegetation is dominant on these soil groups.

#### Residual Soils

Residual soils occupy about 78 percent of the study area. They have developed primarily from interbedded shale and sandstone of the Fort Union Formation (Tongue River Member). In general, the physical and chemical properties of these soils correlate closely with those of the parent material.

The solum (A and B horizons) of these soils is usually less than 20 inches in depth. Soil textures are predominantly medium to moderately fine throughout the profiles. The A and B horizons are commonly brown to dark grayish brown (moist), whereas the C horizons are typically pale brown to yellowish brown (moist). The permeability rate (hydraulic conductivity) of the A and B horizons is generally moderately slow to slow; in the C horizons, it ranges from moderate to very slow depending on the nature of the parent material, i.e., moderate through sandstone and slow to very slow through shale.

These soils are generally calcareous and slightly to moderately saline throughout their profiles. Locally, these soils are also sodic.

Point site soil profiles representative of the residual soils in this study area are described in Tables 15 through 19, Appendix D.

#### Transported (Alluvial/Colluvial) Soils

Transported soils comprise approximately 17 percent of the study area. They have developed over loamy alluvial/colluvial deposits which have accumulated through soil creep, slides, and local wash. Slopes are mostly gentle to moderate on the fans, footslopes, and swales occupied by these soils.

In general, these soils are moderately deep to deep over weathered shale or sandstone. Textures range from medium to fine depending on the nature of the deposits. Colors are typically brown to very dark grayish brown (moist) in the A and B horizons and brown or yellowish brown to light gray (moist) in the C horizons.

The hydraulic conductivity rate in the A and B horizons is generally slow to very slow; in the C horizons, it ranges from moderately slow to slow depending on the nature of the deposits and substratum.

The A and upper B horizons of most of these soils are slightly calcareous, whereas, the lower B and upper C horizons are strongly calcareous. Most of these soils are slightly to moderately saline with the concentration of soluble salts typically reaching a maximum between 60 and 84 inches in depth. Moderately high to high levels of exchangeable sodium were found in some profiles, primarily in the subsurface (B and/or C) horizons. Tables 20 and 21, Appendix D, describe typical profiles of transported soils in this study area.

#### Alluvial Valley Floor Soils

Alluvial Valley Floor soils represent about 5 percent of the study area. They have developed over deep, loamy alluvium derived primarily from shale and sandstone. These soils occupy nearly level bottomlands adjacent to major tributary drainages.

These soils are deep. Textures range from medium to fine, with interspersed coarse lenses being common. The A and B horizons are generally brown (moist), whereas colors in the C horizons vary widely depending on the nature of the deposits.

The A and B horizons are usually moderately slowly permeable; the rate of moisture movement through the C horizons ranges from moderately slow to very slow depending primarily on texture.

Generally, the A and B horizons are noncalcareous or slightly calcareous. The C horizons are strongly calcareous. These soils are typically non-saline to a depth of 24 to 36 inches. Below this, they are often slightly to moderately saline. Most of these soils are nonsodic. However, small areas of sodic alluvial valley floor soils occur locally in this study area, most likely associated with saline seeps. These areas are characterized by micro depression "slick spots" which may be void of vegetation.

Representative profiles of alluvial valley floor soils in this study area are described in Tables 22 and 23, Appendix D.

#### Land Suitability Survey

A semidetalled land suitability survey of the Pumpkin Creek Study Area was made to evaluate and characterize the overburden (includes soil and bedrock) 1/ as a source of material for resurfacing and revegetating the area if it is surface-mined. This survey provides data on the quantity and quality of material for revegetation, ease of stripping and stockpiling the usable material, and other factors which affect the land's suitability

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1/ A glossary defining terms is included in Exhibit 4, Appendix D.

for revegetation. Basic data on the physical and chemical properties of the natural soil bodies and bedrock materials are also provided by this survey.

Land suitability specifications, shown on Table 24, were developed to establish classes for the specific use proposed, i.e., as a source of material for revegetation of surface-mined lands. Four land classes: 1, 2, 3, and 6 were developed. These correspond to classes in the Bureau of Reclamation land classification system.

Factors included in the specifications for quality consideration were: texture, salinity, sodicity, hydraulic conductivity, percent stones (> 3 inches), erodibility, and available water holding capacity. Quantity considerations were based primarily on the depth of the material. Other factors influencing the ease with which suitable material could be selectively stripped and stockpiled were also considered. These included hard bedrock exposures (outcrops) and steep, rough, or complex slopes.

Class 1 lands provide the most desirable and plentiful source of soil material for revegetation. An abundant supply of highly suitable material, which is easily stripped and stockpiled, will be available from this land class. In addition to having an adequate amount of suitable material for reclaiming the immediate area, Class 1 lands can probably provide borrow material for topdressing areas with insufficient suitable material. Class 2 lands contain an adequate supply of resurfacing material to revegetate the immediate area; however, this material is slightly less desirable in quality or somewhat more difficult to strip and stockpile than the material on Class 1 lands. Class 3 lands are similar to those in Class 2, except the deficiencies are more pronounced or a combination of deficiencies exists. Land in this class is marginally suitable for revegetation but, through utilization of good stripping and stockpiling procedures, the requirements for planting media can generally be met. Class 6 lands lack adequate quantities of suitable material to meet the needs for revegetation. If these lands are disturbed by surface mining, it will be necessary to borrow material from Class 1 or 2 lands or modify the material available for revegetation through leaching, addition of chemical amendments, etc.

Table 25 expands the preceding summary description of the land classes and describes the significant characteristics of the major land classes and subclasses.

The land suitability survey was accomplished using Bureau of Reclamation methods and procedures. Field mapping was done on aerial photographs with a scale of 1:12,000. Topographic drawings at a scale of 1:24,000 with 20-foot contour intervals were used for reference. An Abney hand level was used to supplement the slope data on the topographic drawings.

Representative (Point Site) soil profiles typical of extensive areas of Class 1, 2, 3, and 6 lands were described, sampled, and analyzed in detail. Additional profiles were recorded in the heterogeneous soil areas to show variations within the delineated areas. This information

was supplemented by nonrecorded profile examinations as required. Nonrecorded profiles are typically located in transitional areas between soil types to more accurately locate boundaries.

In the field appraisal, the top 16 inches of the soil profiles were exposed with a tile spade. A hand auger or hydraulic coring machine was then used to penetrate the overburden to a depth of 10 feet unless hard bedrock was encountered. Soil structure, texture, consistence, color, and other observable features of the exposed profile such as salinity, sodicity, and root distributions were recorded. Lime content was checked with dilute hydrochloric acid. Samples were collected from many of the exposed profiles. Evaluation of the soil material for hydraulic conductivity and available water holding capacity in relation to the reclaimed profile was a major consideration in the field evaluation. Using these basic soil evaluations along with observations of other land features such as surface stones, exposed hard bedrock, and slope, a land suitability class was tentatively assigned each delineated area while in the field. The suitability classes, when finalized, were recorded on land classification maps, Plates 24 through 32.

A soil laboratory was used in connection with the land suitability survey and screenable tests were performed on all soil samples. These tests included disturbed hydraulic conductivity, salinity, pH, 15-bar moisture retention, and settling volume. More detailed soil analyses were then made as required. Exhibit 1, Appendix D describes the screenable testing procedures used in the laboratory.

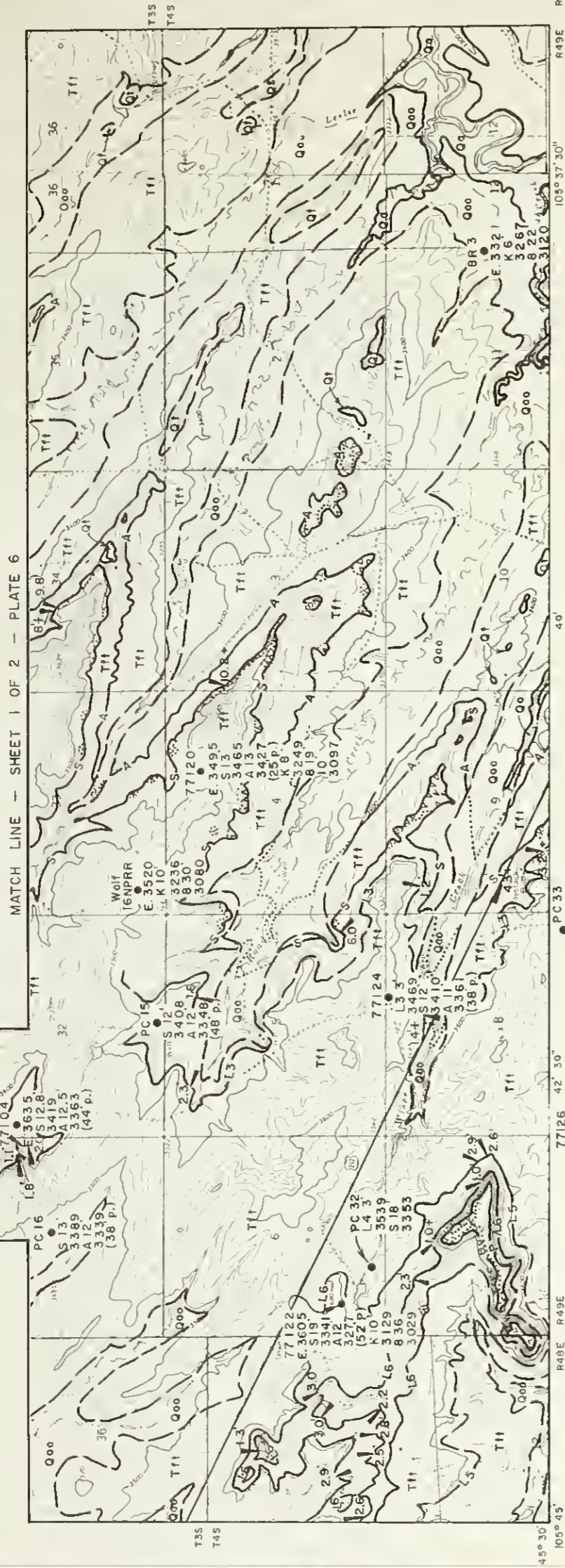
Complete soil analyses were performed on all samples from Point Site profiles representative of the major soil categories for the land suitability survey. The analyses listed in Exhibit 2, Appendix D were performed as needed for proper overburden evaluation.

### Results of Land Suitability Survey

The results of the land suitability survey are presented on semidetailed drawings, Plates 24 through 32, which show the areal distribution of the various land classes, soil deficiencies, topographic deficiencies, profile notes of soil borings, and the results of selected laboratory analyses. This information is also summarized on Plates 33 through 40.

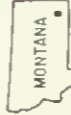
Plates 33 through 36 describe the location and depth of topsoiling material that is suitable for surface placement in reconstructed profiles. Plates 37 through 40 indicate the location and quality of material that is suitable for subsurface placement below the primary plant rooting zone.

Table 26 lists the acreage of each land class occurring in the study area. The results in this table indicate that 64.5 percent of the land in the Pumpkin Creek Study Area contains an adequate supply of suitable overburden (soil and/or bedrock to a depth of 10 feet) for revegetation. This includes Class 1, 2, and 3 lands. The remaining 35.5 percent of the study area, designated as Class 6, will require borrowed material from Class 1 or 2 lands or modification of the available material in order to provide adequate plant media for revegetation.



Base from U.S. Geological Survey Box Elder Creek,  
Leslie Creek, Coalwood, and Olive Quadrangle maps

CONTOUR INTERVAL 20 FEET



SCALE 1:24,000



## PRELIMINARY GEOLOGIC MAP OF THE PUMPKIN CREEK EMRIA STUDY SITE

BOX ELDER CREEK, LESLIE CREEK, COALWOOD, AND OLIVE QUADRANGLES.

POWDER RIVER COUNTY, MONTANA

BY  
MARGUERITE GLENN

1978

## EXPLANATION

**ALLUVIUM (HOLOCENE)**--Unconsolidated clay, silt, sand, and lenses of gravel in and adjacent to the principal streams. Areas shown as Qa are the areas of alluvial valley floor and include stream channel, flood plain, and low alluvial terrace deposits. Some very small areas of it are not shown. In the southeast part of the study site these areas are generally the same as the areas of Qa mapped by Maide and Boyles (1976, Stacey 4 SW map)

**OTHER ALLUVIAL DEPOSITS (HOLOCENE)**--Unconsolidated clay, silt, sand, and lenses of gravel adjacent to valley floors of principal streams, in and adjacent to tributary streams, and in the upper reaches of the principal streams. Includes upper stream channel, older flood plain, alluvial terrace deposits, and, locally, some alluvial fan and slopewash deposits

**TERRACE DEPOSITS (HOLOCENE AND PLEISTOCENE)**--Unconsolidated silt, sand, and gravel; contains pebbles, cobbles, and boulders of clinker, siltstone, and silty limestone, and sparse petrified wood; at terrace levels as much as 160 feet (49 m) above the principal streams; probably equivalent to Qcp1 and Qcp3 as mapped by Bass (1932) in the Ashland coal field and to the Qtu, Qtp2, and Qtp3 as mapped by Bryson (1951) in the Coalwood coal field

**TONGUE RIVER MEMBER OF THE FORT UNION FORMATION (PALEOCENE)**--Light gray, yellowish gray, and tan mudstone, siltstone, sandstone, and silty limestone; gray shale; brown carbonaceous shale, and coal. Unidentified pelecypod and gastropod fossils were observed in the NW corner of Sec. 20, T. 3 S., R. 49 E., in carbonaceous shale about 10 feet (3 m) below the base of a tan very fine grained massive sandstone and about 100 feet (30.5 m) above the base of the Sawyer coal. Silicified wood is abundant in the Stump coalbed, but is rare elsewhere. The exposed thickness of the Tongue River Member is about 800 feet (244 m)

**CONTACT**--Dashed where approximately located

**FAULT**--U, upthrown side; D, downthrown side

**COAL BED**--Contact drawn on base of bed. Dashed where inferred; dotted where concealed by alluvial deposits. Triangle indicates a locality at which coal was measured or observed. Thickness shown is in feet. Letters and numbers designate names of coal beds as follows:

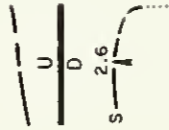
- P Pawnee
- L6 Local, unnamed coal, 70-90 feet (21-27 m) below Pawnee and 300 feet (91 m) above Sawyer
- X X, seen only as clinker 55-80 feet (17-24 m) above Stump
- L5 Local, unnamed coal, 120-130 feet (38-40 m) below Pawnee and 250 feet (76 m) above Sawyer. May equal Stump
- St Stump, 240-300 feet (73-92 m) above Sawyer
- L4 Local, unnamed coal, 185-200 feet (56-61 m) above Sawyer

Qa

Qoo

Qt

Tt1



- MW Mackin-Walker, 80-120 feet (24-38 m) above Sawyer, locally splits into MMI (lower) and MMZ (upper), as much as 40 feet (12 m) apart
- L3 Local, unnamed coal, 50-75 feet (15-23 m) above Sawyer
- S Sawyer
- A A, split from base of Sawyer by 2-60 feet (1-19 m) of rock
- K Knobloch, 120-140 feet (38-43 m) below Sawyer
- FG Flowers-Goodale, 35-60 feet (12-19 m) below Knobloch, locally splits into FGI (lower) and FG2 (upper), about 10 feet (3 m) apart
- L2 Local, unnamed coal, about 15 feet (5 m) below Flowers-Goodale
- B Broadus, correlated with Flowers-Goodale (Bryson, 1951, p. 83)
- An Allen, about 40 feet (12 m) below Flowers-Goodale
- L1 Local, unnamed coal, about 100 feet (30 m) below Flowers-Goodale

**AREA OF BURNED COAL BED**--Dotted line indicates approximate limit of burned coal. Heat from the burning coal bed has baked or fused the overlying rocks into a predominantly reddish resistant rock called clinker

PWW1

E. 3600

S. 15

3430

3415

(1 P)

Drilled for the EMRIA study and their respective columns on the accompanying geologic sections are shown as follows:

PWW1-PWW11, Holes drilled by U.S. Geological Survey  
76101, 77102-77110, Holes drilled by the U.S. Bureau of Reclamation  
77118-77137, Holes drilled by Montana Bureau of Mines and Geology and U.S. Geological Survey

Previously drilled holes from which data (Matson, Blumer, and Megel in 1973, pls. 15, 17; geophysical and drillers' logs) were used are shown as follows:

US-A--US-G, US-O and US-P, Holes drilled by U.S. Geological Survey  
BR9, BR10, PC1-PC17, PC26, PC27, PC32, and PC33, Holes drilled by Northern Pacific Railroad and Montana Bureau of Mines and Geology  
Greer-El Paso 100-5 NPRR, Wolf 13, 15, 16, and 14-13 NPRR, Abandoned holes drilled in exploration for oil and gas

ABANDONED COAL MINE

## REFERENCE

- Bass, N.W. 1932, The Ashland coal field, Rosebud, Powder River, and Custer Counties, Montana: U.S. Geol. Survey Bull. 831-B, p. 19-105.
- Bryson, R.P., 1951, The Coalwood coal field, Powder River County, Montana: U.S. Geol. Survey Bull. 973-B, p. 23-106.
- Maide, W.E., and Boyles, J.M., 1976, Maps of alluvial valley floors and strippable coal in forty-two 7 1/2 minute quadrangles, Big Horn, Rosebud, and Powder River Counties, Southeast Montana: U.S. Geol. Survey Open File Rept. 76-162.
- Matson, R.E., Blumer, J.W., and Megel, L.A., 1973, Quality and reserves of strippable coal, selected deposits, southeastern Montana: Montana Bur. Mines and Geology Bull. 91, 135 p.

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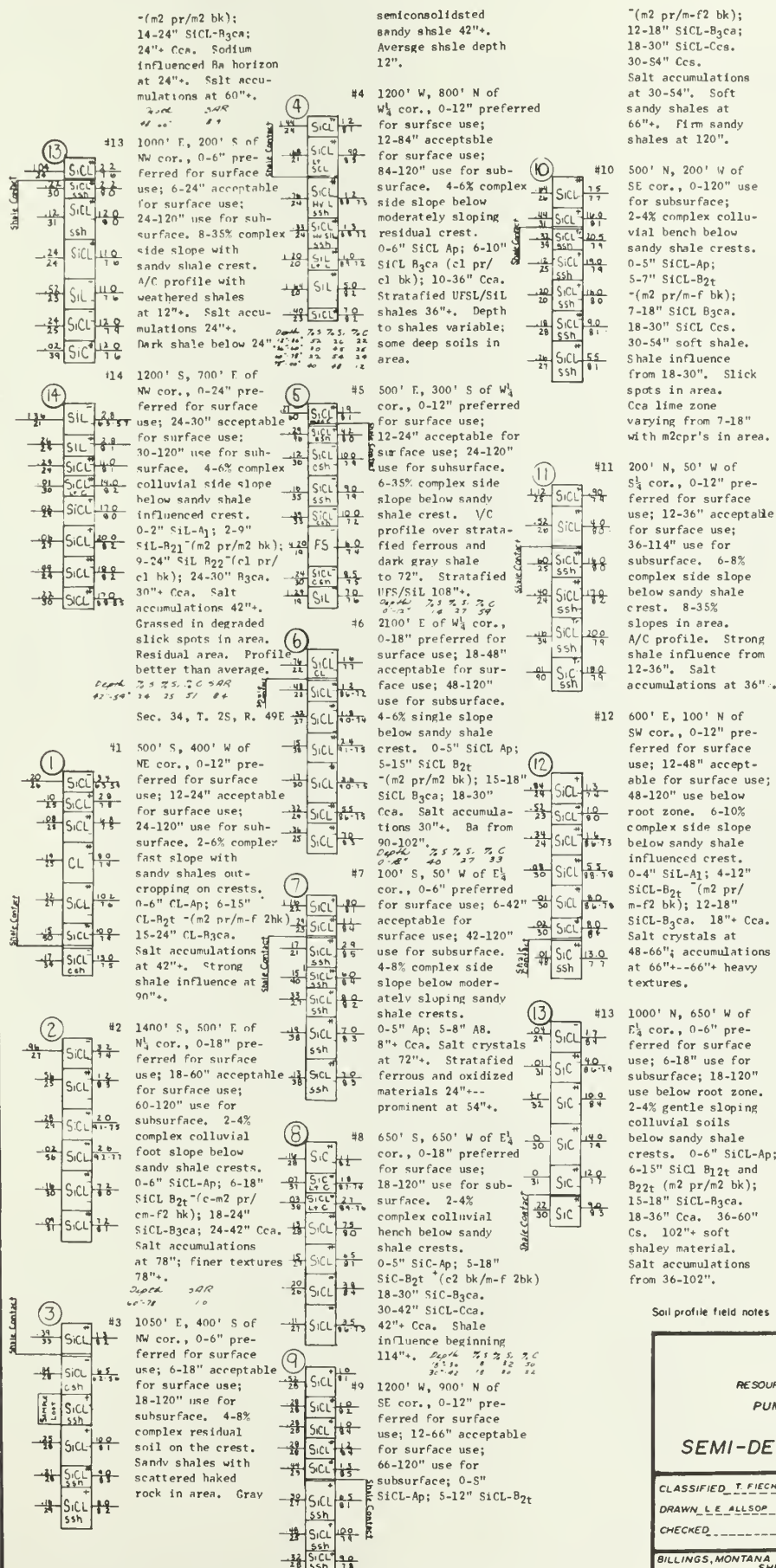
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SOIL PROFILE NOTES  
PROFILE REPRESENTS 5' DEPTH

3 SOIL PROFILE NUMBER

CL	28 --- 28 EC mmhos/cm Soil Est
	84-B0 8.4 pH 1:5 Soil-Water Suspension
	B OpH Soil-CaCl <sub>2</sub> Suspension
	65 Hydraulic Conductivity in/hr
	(Disturbed Samples)
	24 Settling Volume

65  
24

## SOIL PROFILE SYMBOLS

CB	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiL	Silty Clay Loam
SC	Sandy Clay
C	Clay
Si	Silly Clay
Sh	Shale
Ss	Sandstone
F	Fine
Li	Light
M	Medium
H	Heavy

STRUCTURE ABBREVIATIONS	
<u>Size</u>	
	very fine .....vf
	fine .....f
	medium .....m
	coarse .....c
	very coarse .....vc
<u>Grade</u>	
	structureless ..0

Strong .....3  
Type

```

platy .....pl
prismatic .....pr
columnar .....cpr
blocky .....bk
angular blocky .abk
subangular blocky .sbk
granular .....gr
crumb .....cr
single grain .....sg
massive .....m

```

### MISCELLANEOUS A8REVLTATIONS

calcic horizon .....Ca  
sodium adsorption-ratio ...SAR  
settling volume .....SV  
creviced rock ....CR

INFORMATIVE SYMBOLS  
OVERBURDEN DEFICIENCIES  
(for plant media)

- o Sodicity
- s Solinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Stoniness

### TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Indurated sandstone, shale, or baked rock
- c Cover

## NOTE

Soil profile field notes continued from Sheet 2 of 9. Drawing No.

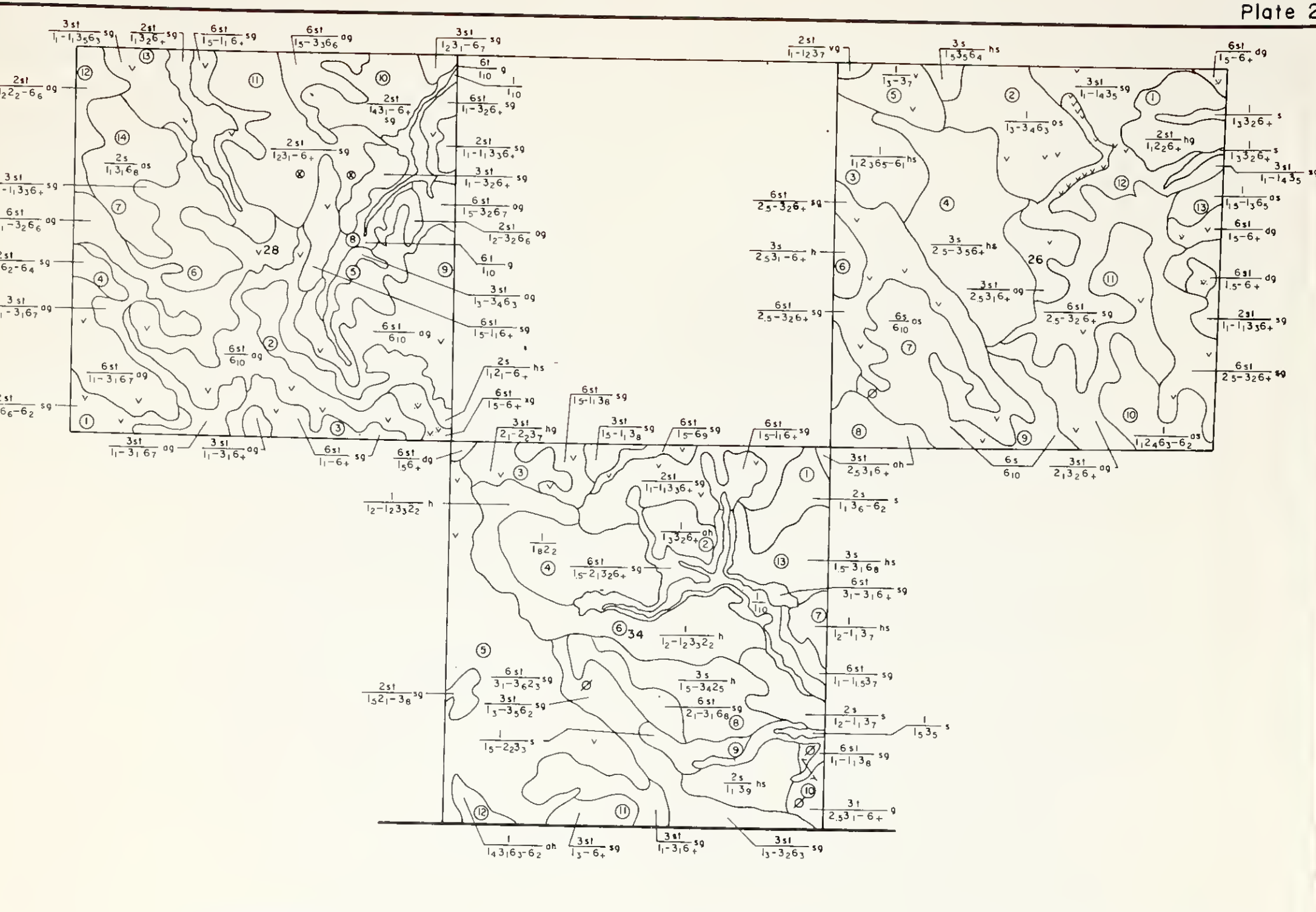
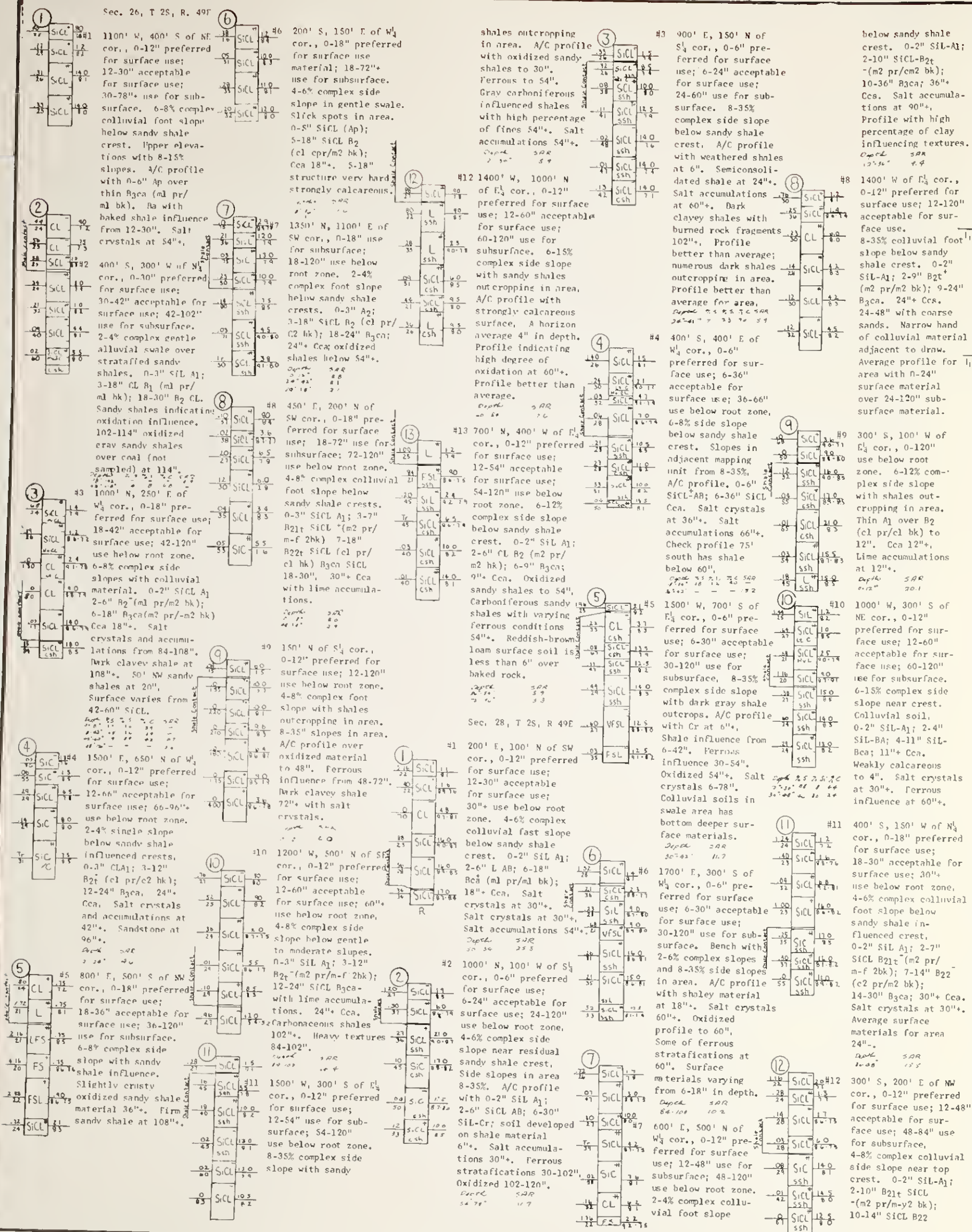
UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF RECLAMATION  
RESOURCE & POTENTIAL RECLAMATION EVALUATION  
PUMPKIN CREEK COALFIELD-MONTANA  
PUMPKIN CREEK STUDY AREA

### SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIED T FIECHTL SUBMITTED \_\_\_\_\_  
DRAWN LE ALLSOP RECOMMENDED \_\_\_\_\_  
CHECKED \_\_\_\_\_ APPROVED \_\_\_\_\_

BILLINGS, MONTANA OCTOBER, 1978 1305-600-224





**SOIL PROFILE NOTES**  
PROFILE REPRESENTS 5' DEPTH

**3** SOIL PROFILE NUMBER

C.L.	2.8--2.8 EC mmhos/cm. Sal Exl
Li.C.	8.4-8.0 8.4 pM 1:5 Soil-Water Suspension
Gr.	8.0 pM Soil-Cl <sub>2</sub> Suspension
	----- 65 Hydraulic Conductivity in/hr (Disturbed Samples)
	----- 24 Settling Volume

**STRUCTURE ABBREVIATIONS**

Size	very fine .....vf
	fine .....f
	medium .....m
	coarse .....c
	very coarse .....vc
Grade	structureless ..0
	weak .....1
	moderate .....2
	strong .....3
Type	platy .....pl
	prismatic .....pr
	columnar .....cpr
	blocky .....bk
	angular blocky .abk
	subangular blocky .sbk
	granular .....gr
	crumb .....cr
	single grain .....sg
	massive .....m
	Light
	Medium
	Heavy

**LAND CLASSIFICATION SYMBOLS**

**LAND CLASS**

**SURFACE LAYER**

Depth (11)

**SECOND LAYER**

Depth (11)

**INFORMATIVE SYMBOLS**

**OVERBURDEN DEFICIENCIES**  
(for plant medio)

**LAND FEATURES**

**WATER FEATURES**

**CONVENTIONAL AND SPECIAL MAP SYMBOLS**

**SECTION 26,28,34, T.2 S.-R.49 E.**

**UNITED STATES**  
**DEPARTMENT OF THE INTERIOR**  
**BUREAU OF RECLAMATION**

**RESOURCE & POTENTIAL RECLAMATION EVALUATION**  
**PUMPKIN CREEK COALFIELD-MONTANA**  
**PUMPKIN CREEK STUDY AREA**

**SEMI-DETAILED LAND CLASSIFICATION**

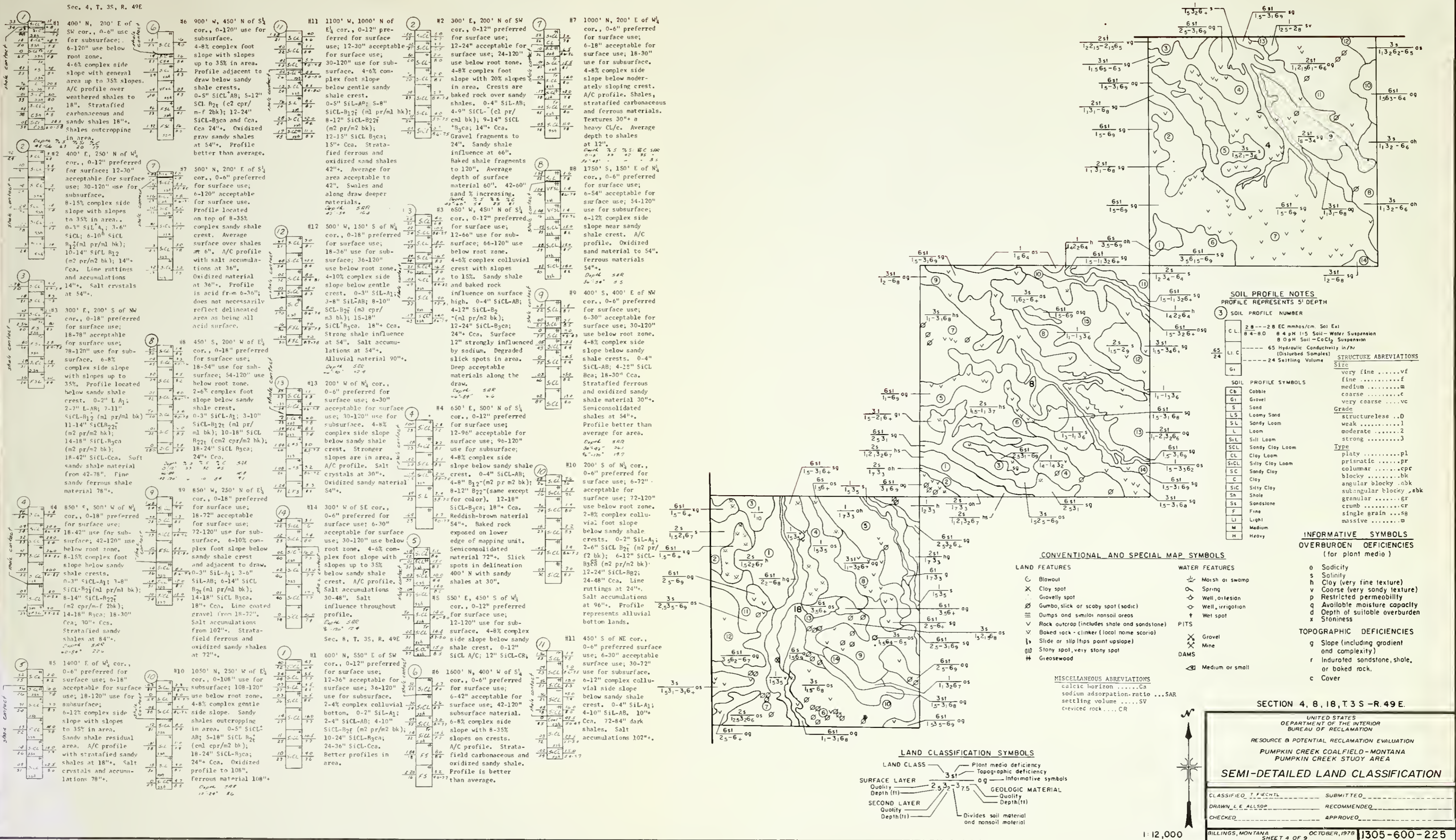
**CLASSIFIED BY FIELD** \_\_\_\_\_ **SUBMITTED** \_\_\_\_\_

**DRAWN BY** ALLSOP \_\_\_\_\_ **RECOMMENDED** \_\_\_\_\_

**CHECKED** \_\_\_\_\_ **APPROVED** \_\_\_\_\_

**BILLINGS, MONTANA** \_\_\_\_\_ **OCTOBER, 1978** \_\_\_\_\_ **1305-600-223**





SECTION 4, 8, 18, T. 3 S. - R. 49 E.

UNITED STATES  
 DEPARTMENT OF THE INTERIOR  
 BUREAU OF RECLAMATION

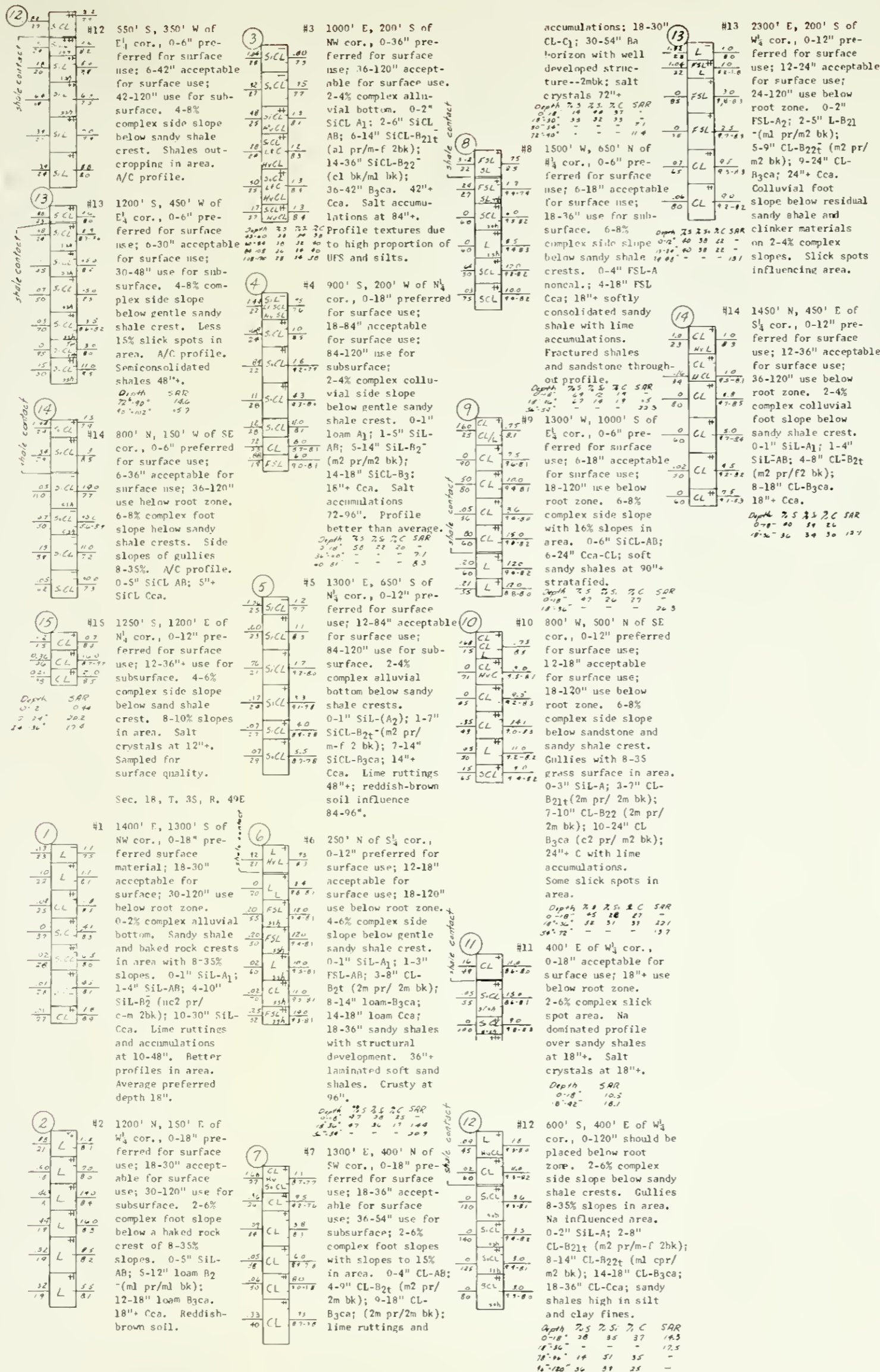
RESOURCE & POTENTIAL RECLAMATION EVALUATION  
 PUMPKIN CREEK COALFIELD-MONTANA  
 PUMPKIN CREEK STUDY AREA

**SEMI-DETAILED LAND CLASSIFICATION**

CLASSIFIED BY: J. F. ECHTEL	SUBMITTED BY:
DRAWN BY: E. ALLSOP	RECOMMENDED BY:
CHECKED BY:	APPROVED BY:

BILLINGS, MONTANA OCTOBER, 1978 SHEET 4 OF 9 1305-600-225





# SOIL PROFILE NOTES

## PROFILE REPRESENTS 5' DEPTH

3	SOIL PROFILE NUMBER
C.L.	2.8--2.8 EC mmhos/cm Sol Est
	8.4--8.0 8.4 pH 1:5 Soil-Water Suspension
	8.0 pH Soil-CaCl <sub>2</sub> Suspension
65	65 Hydraulic Conductivity in/hr (Disturbed Samples)
24	24 Settling Volume

# SOIL PROFILE SYMBOLS

Cb	Cobble
G	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
Sil	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
LI	Light
M	Medium
H	Heavy

# STRUCTURE ABBREVIATIONS

Size	very fine .....vf
	fine .....f
	medium .....m
	coarse .....c
	very coarse .....vc
Grade	structureless ..0
	weak .....1
	moderate .....2
	strong .....3

Type	platy .....pl
	prismatic .....pr
	columnar .....cpr
	blocky .....bk
	angular blocky .abk
	subangular blocky .sbk
	granular .....gr
	crumb .....cr
	single grain ....sg
	massive .....m

# MISCELLANEOUS ABBREVIATIONS

calic horizon	....Ca
sodium adsorption-ratio	...SAR
settling volume	....SV
cracked rock	....CR

# INFORMATIVE SYMBOLS

## OVERBURDEN DEFICIENCIES (for plant medio)

a	Sodicity
s	Solinity
h	Clay (very fine texture)
v	Coarse (very sandy texture)
p	Restricted permeability
q	Available moisture capacity
d	Depth of suitable overburden
x	Stoniness

## TOPOGRAPHIC DEFICIENCIES

g	Slope (including gradient and complexity)
r	Indurated sandstone, shale, or baked rock.
c	Cover

# NOTE

Soil profile field notes continued from Sheet 4 of 9, Drawing No

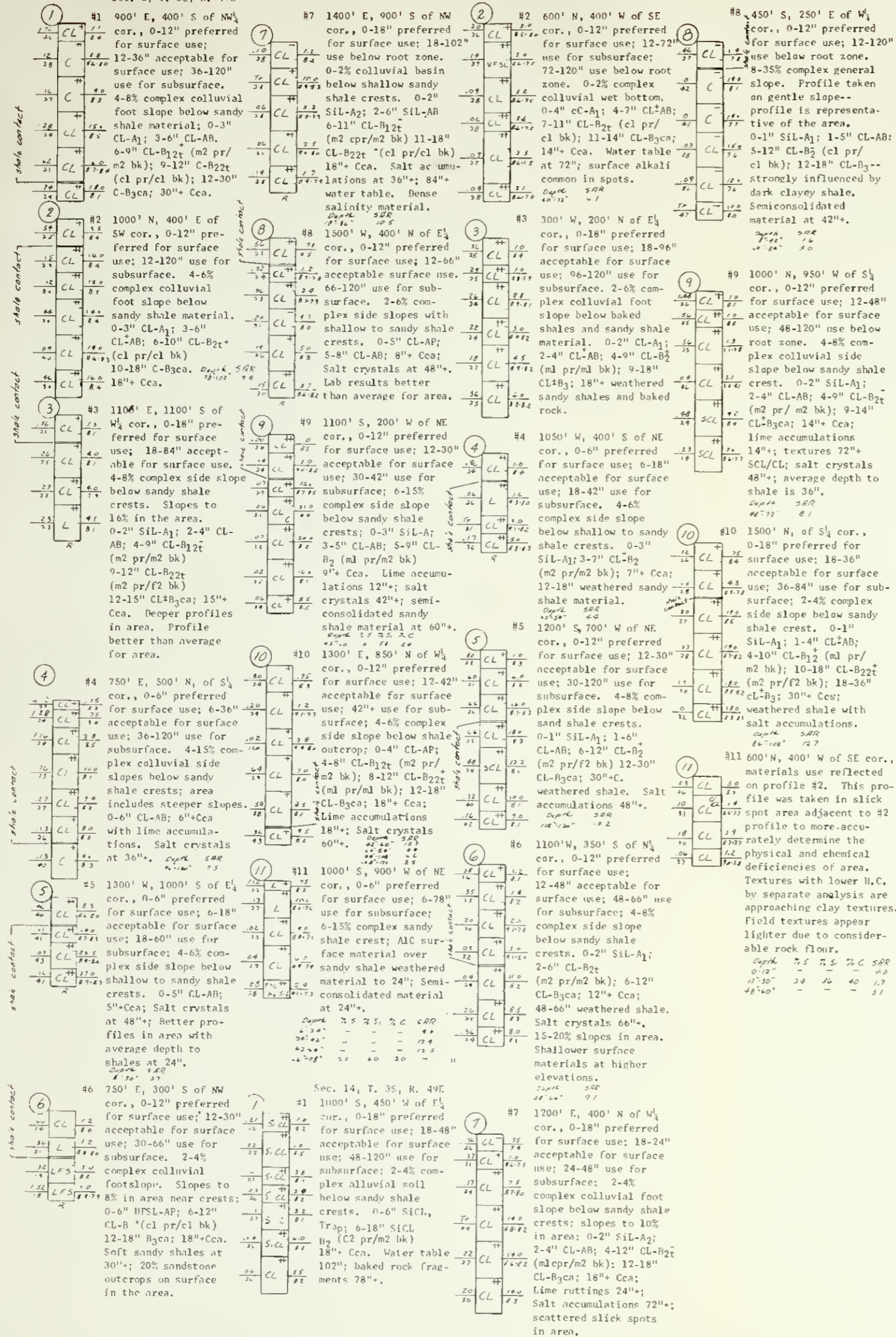
UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF RECLAMATION  
RESOURCE & POTENTIAL RECLAMATION EVALUATION  
PUMPKIN CREEK COALFIELD-MONTANA  
PUMPKIN CREEK STUDY AREA

# SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIED	T. FIECHTL	SUBMITTED	
DRAWN	L. E. ALLSOP	RECOMMENDED	
CHECKED		APPROVED	
BILLINGS, MONTANA SHEET 5 OF 9 OCTOBER, 1978 1305-600-226			



Sec. 2, T. 3S, R. 49E



## CONVENTIONAL AND SPECIAL MAP SYMBOLS

## LAND FEATURES

- Blowout
- Clay spot
- Gravelly spot
- Gumbo, slick or scaly spot (sodic)
- Dumps and similar nonsol areas
- Rock outcrop (includes shale and sandstone)
- Baked rock - clinker (local name scoria)
- Slide or slip (tips point up slope)
- Stony spot, very stony spot
- Greensward

## WATER FEATURES

- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

## PITS

- Gravel
- Mine

## DAMS

- Medium or small

## INFORMATIVE SYMBOLS

## OVERBUREN DEFICIENCIES

(for plant media)

- Sodicity
- Salinity
- Clay (very fine texture)
- Coarse (very sandy texture)
- Restricted permeability
- Available moisture capacity
- Depth of suitable overburden
- Stoniness

## TOPOGRAPHIC DEFICIENCIES

- Slope (including gradient and complexity)
- Indurated sandstone, shale, or baked rock
- Cover

## SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH

## 3 SOIL PROFILE NUMBER

- CL 2.8--2.8 EC mmhos/cm Sal. Est.  
8.4-8.0 8.4 pH 1.5 Soil-Water Suspension  
8.0 pH Soil-CaCl<sub>2</sub> Suspension  
----- 65 Hydraulic Conductivity in/hr  
(Disturbed Samples)  
----- 24 Settling Volume

## STRUCTURE ABBREVIATIONS

- Size
- Grade
- Type
- very fine .....ve
- fine .....f
- medium .....m
- coarse .....c
- very coarse .....vc
- structureless ..0
- weak .....1
- moderate .....2
- strong .....3
- platy .....pl
- prismatic .....pr
- columnar .....cpr
- blocky .....bk
- angular blocky .abk
- subangular blocky .sbk
- granular .....gr
- crumb .....cr
- single grain .....sg
- massive .....m

## LAND CLASSIFICATION SYMBOLS

- LAND CLASS
- PLANT MEDIA DEFICIENCY
- TOPOGRAPHIC DEFICIENCY
- INFORMATIVE SYMBOLS
- GEOLOGIC MATERIAL
- QUALITY
- DEPTH (ft)
- DIVIDES SOIL MATERIAL AND NONSOIL MATERIAL

## SECTION 2, 14, T. 3S - R. 49E

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF RECLAMATIONRESOURCE & POTENTIAL RECLAMATION EVALUATION  
PUMPKIN CREEK COALFIELD - MONTANA  
PUMPKIN CREEK STUDY AREA

## SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIED BY: F. EICHTL

SUBMITTED

DRAWN BY: L. E. ALLSOP

RECOMMENDED

CHECKED

APPROVED

BILLINGS, MONTANA

SHEET 6 OF 9

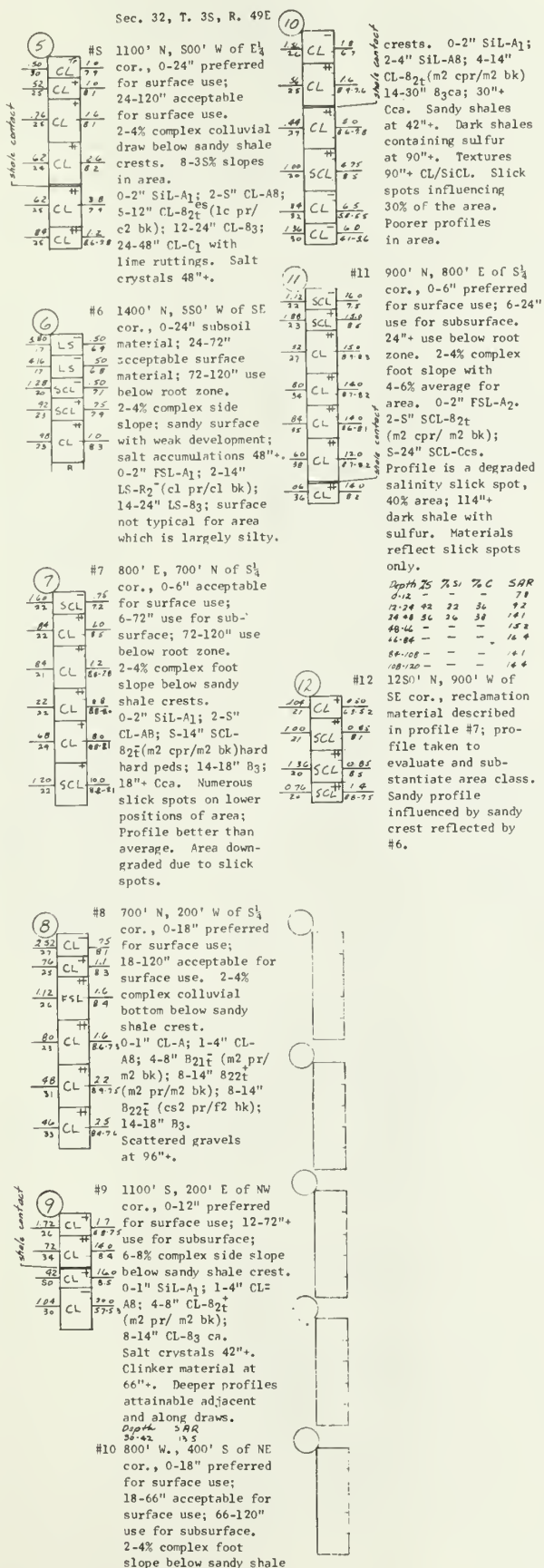
OCTOBER, 1978

1305-600-227

1:12,000



Sec. 32, T. 3S, R. 49E

SOIL PROFILE NOTES  
PROFILE REPRESENTS 5' DEPTH

## (3) SOIL PROFILE NUMBER

CL	2.0 --- 2.8 EC mmhos/cm	Sal Est
Li.C	8.4-8.0	8.4 pH 1:5 Soil-Water Suspension
Gr	0.0 pH	Soil-CoCl <sub>2</sub> Suspension
	65	Hydraulic Conductivity in/hr (Disturbed Samples)
	24	Settling Volume

## SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
St	Sandstone
F	Fine
Li	Light
M	Medium
H	Heavy

## STRUCTURE ABBREVIATIONS

Size	
very fine	.....vf
fine	.....f
medium	.....m
coarse	.....c
very coarse	.....vc
Grade	
structureless	..0
weak	.....1
moderate	.....2
strong	.....3
Type	
platy	.....pl
prismatic	.....pr
columnar	.....cpr
blocky	.....bk
angular blocky	..abk
subangular blocky	..sbk
granular	.....gr
crumb	.....cr
single grain	..sg
massive	.....m

## MISCELLANEOUS ABBREVIATIONS

calcic horizon	.....Ca
sodium adsorption-ratio	...SAR
settling volume	.....SV
cracked rock	....CR

INFORMATIVE SYMBOLS  
OVERBURDEN DEFICIENCIES  
(for plant media)

- a Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Stoniness

## TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Indurated sandstone, shale, or baked rock.
- c Cover

## NOTE

Soil profile field notes continued from Sheet 7 of 9, Drawing No.

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
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RESOURCE & POTENTIAL RECLAMATION EVALUATION  
PUMPKIN CREEK COALFIELD-MONTANA  
PUMPKIN CREEK STUDY AREA

## SEMI-DETAILED LAND CLASSIFICATION

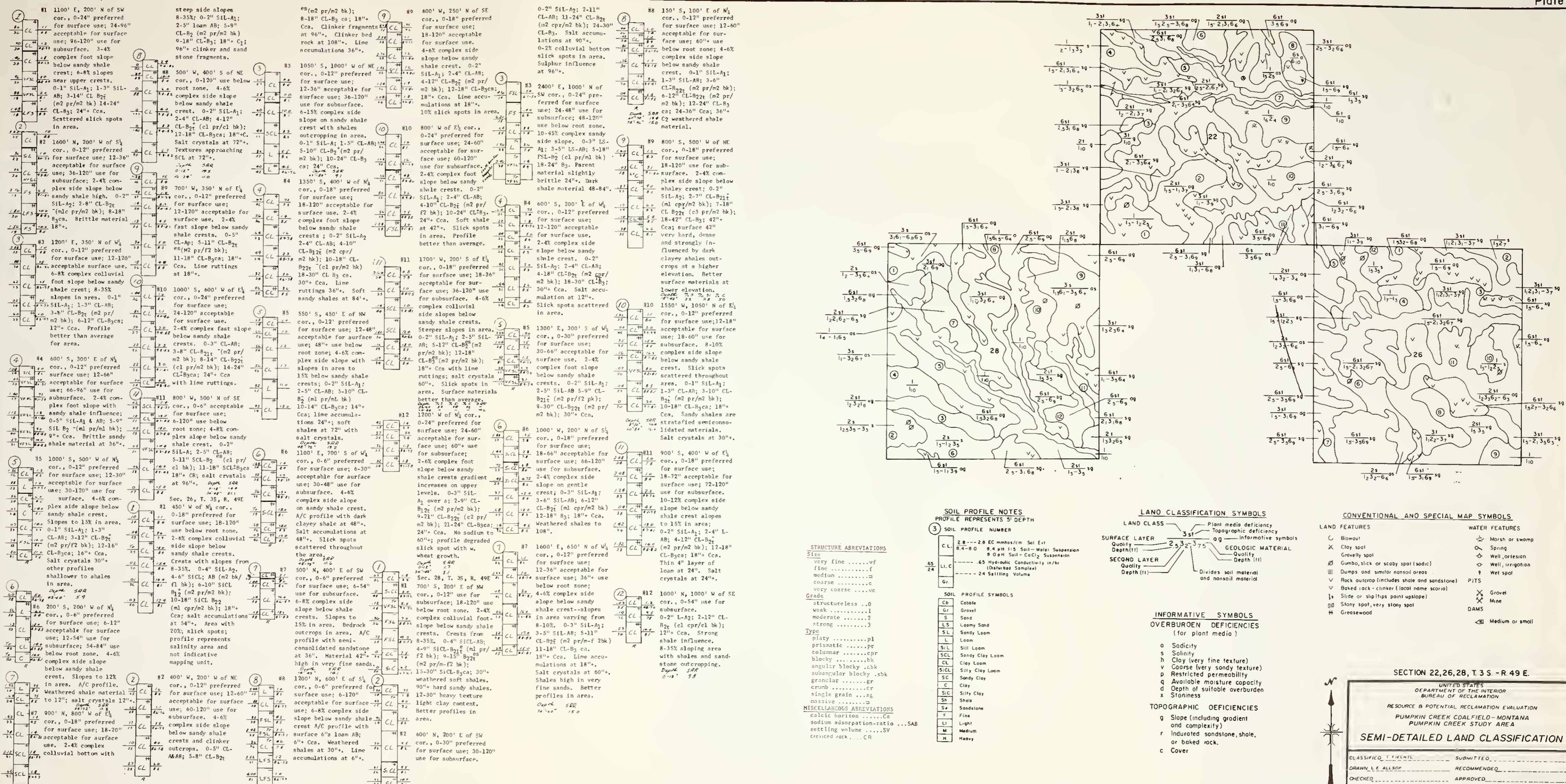
CLASSIFIED BY T. FIECHTL	SUBMITTED BY
DRAWN BY L. E. ALLSOP	RECOMMENDED BY
CHECKED BY	APPROVED BY



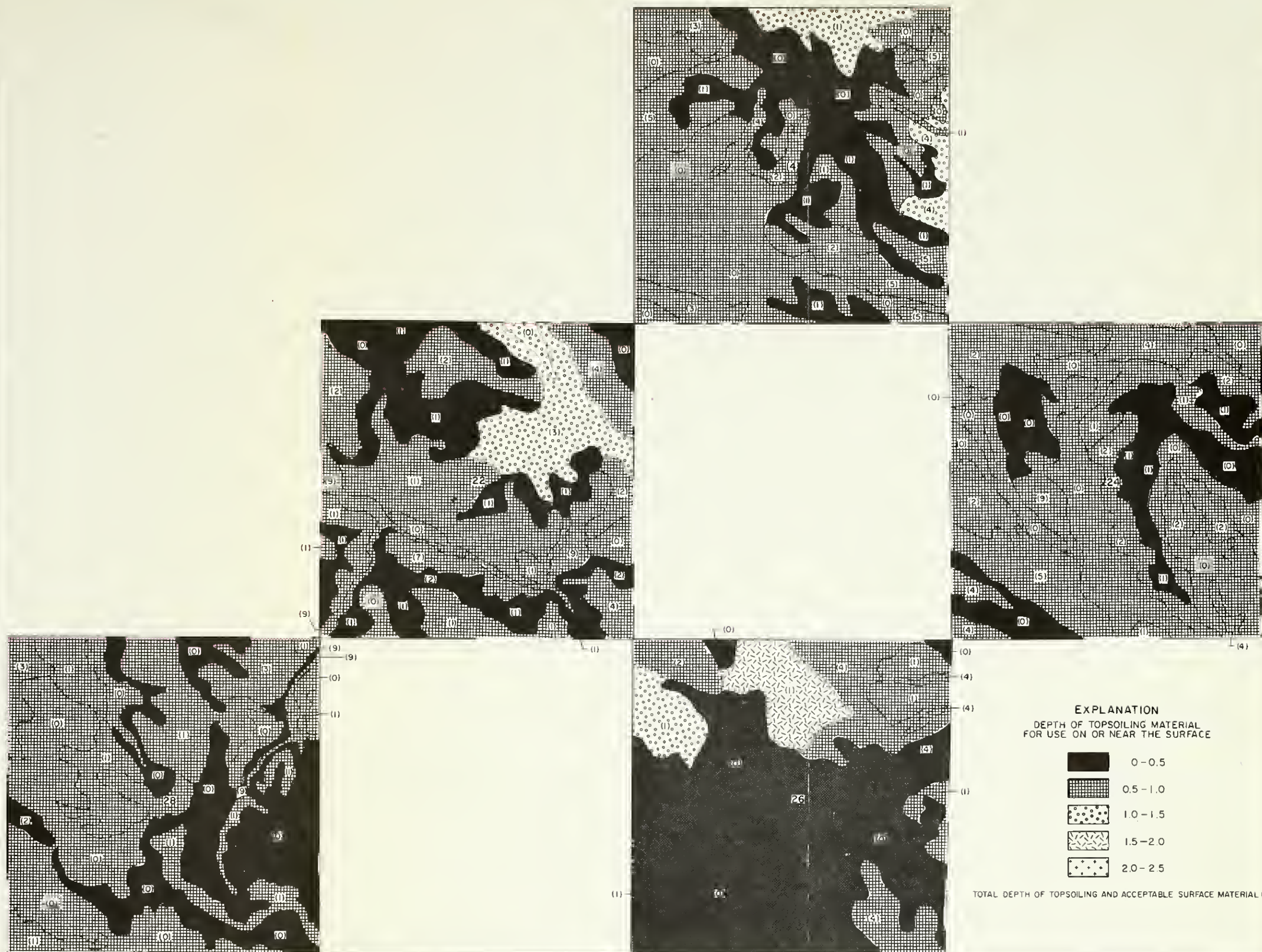




Sec. 22, T. 3S, R. 49E







EXPLANATION  
DEPTH OF TOPSOILING MATERIAL  
FOR USE ON OR NEAR THE SURFACE

	0-0.5
	0.5-1.0
	1.0-1.5
	1.5-2.0
	2.0-2.5

TOTAL DEPTH OF TOPSOILING AND ACCEPTABLE SURFACE MATERIAL (2)

1:12,000

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF RECLAMATION  
RESOURCE & POTENTIAL RECLAMATION EVALUATION

PUMPKIN CREEK COALFIELD-MONTANA  
PUMPKIN CREEK STUDY AREA

TOPSOILING MATERIAL

CLASSIFIED T. FIECHTL	SUBMITTED
DRAWN L. E. ALLSOP	RECOMMENDED
CHECKED	APPROVED
BILLINGS, MONTANA OCTOBER, 1978 SHEET 1 OF 4	
1305-600-231	

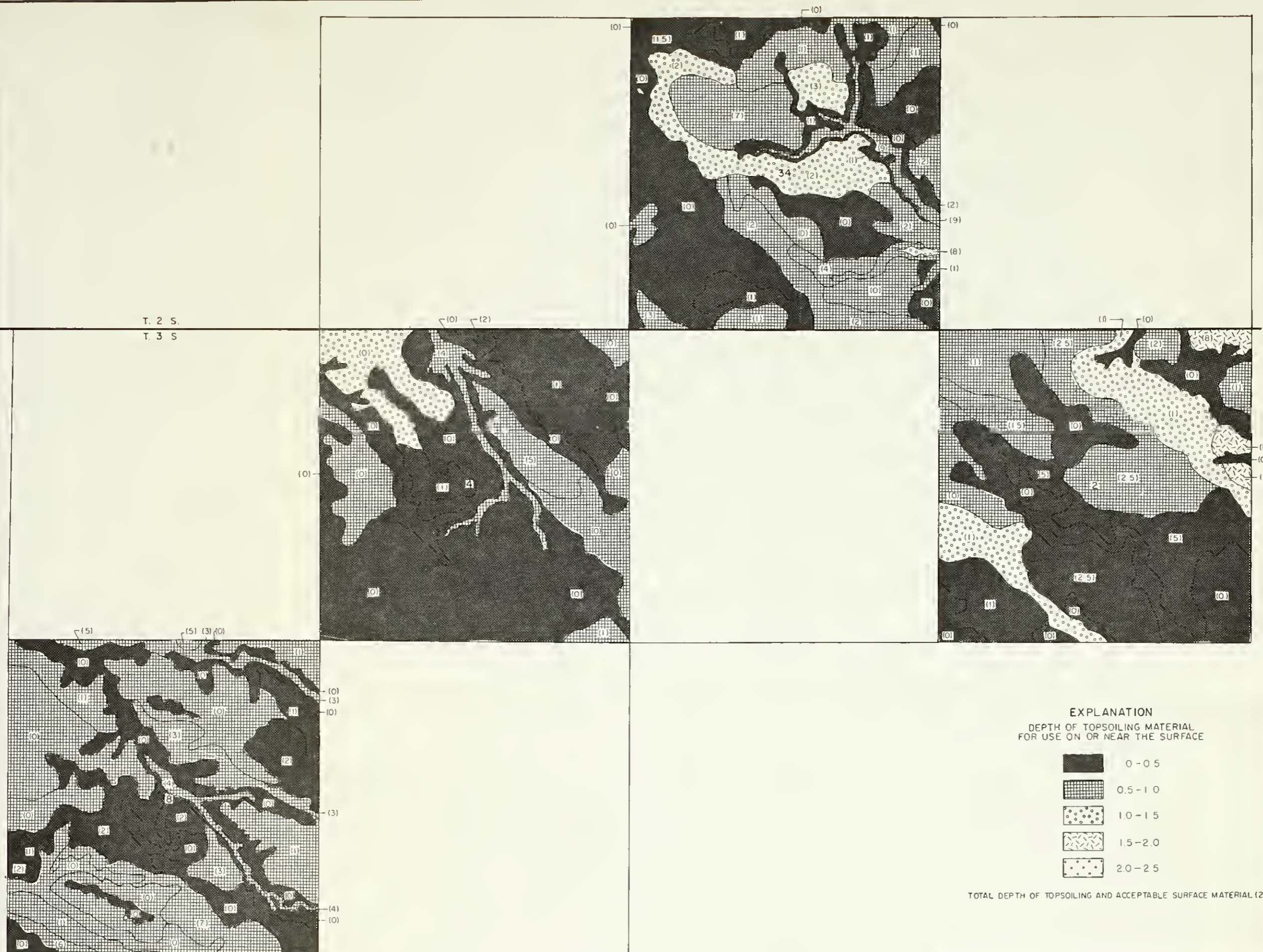
NOTE

Topsoiling material, as used in this report includes that portion of the overburden (soil mantle and bedrock) that is capable of sustained plant production. The material for use on or near the surface is nonsaline and permeable. It has good tilth, retains adequate moisture and contains no known toxic elements. Additional material requiring special placement is similar, but it is usually highly saline. However, the soluble salts will readily leach from material subjected to downward movement of natural precipitation.

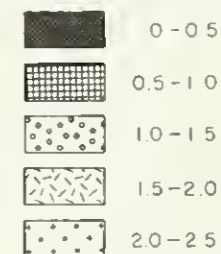
Multiply feet by 0.3048 to obtain meters.

T. 2 S. - R. 49 E.  
Sections 14, 22, 24, 26, 28





EXPLANATION  
DEPTH OF TOPSOILING MATERIAL  
FOR USE ON OR NEAR THE SURFACE



TOTAL DEPTH OF TOPSOILING AND ACCEPTABLE SURFACE MATERIAL (2)

1:12,000

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

PUMPKIN CREEK COALFIELD - MONTANA  
PUMPKIN CREEK STUDY AREA

TOPSOILING MATERIAL

CLASSIFIED T. FIECHTL	SUBMITTED
DRAWN L. E. ALLSOP	RECOMMENDED
CHECKED	APPROVED
BILLINGS, MONTANA	OCTOBER, 1978
SHEET 2 OF 4	1305-600-232

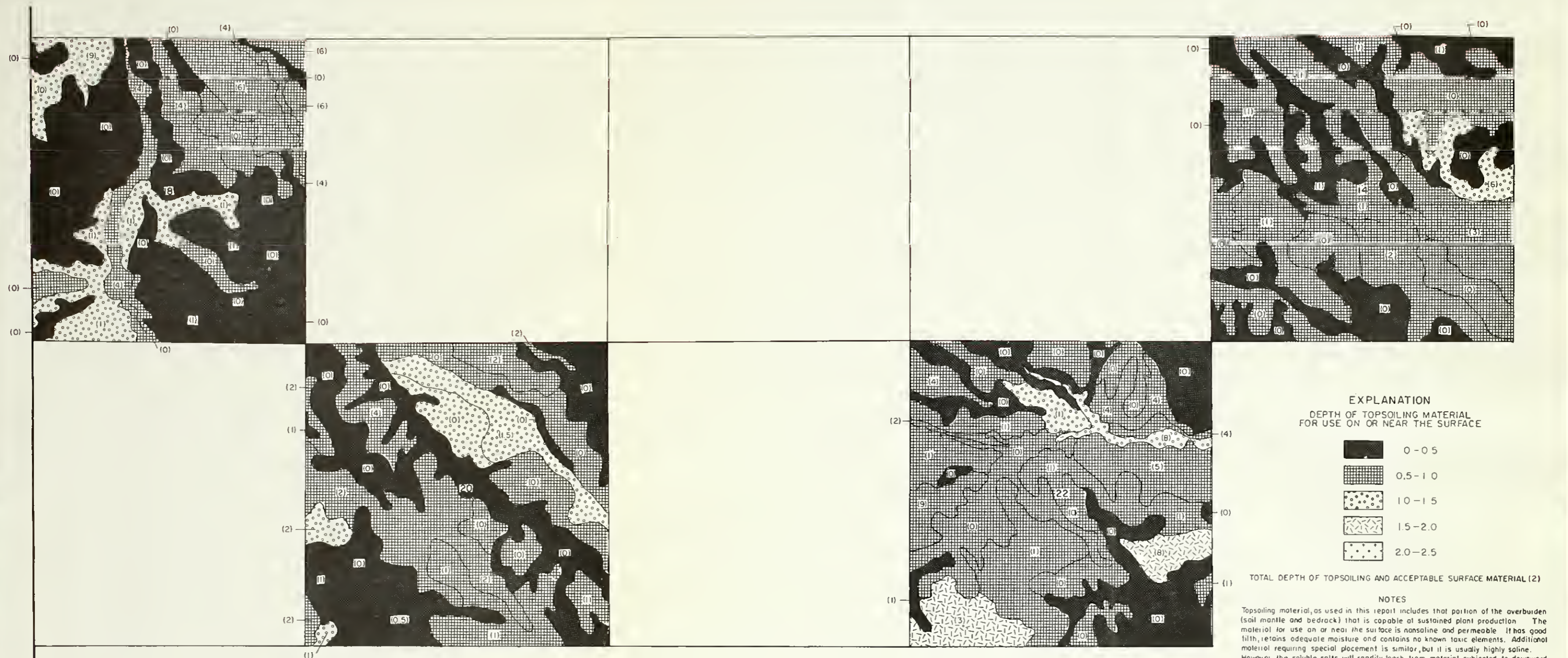
NOTES

Topsoiling material, as used in this report includes that portion of the overburden (soil mantle and bedrock) that is capable of sustained plant production. The material for use on or near the surface is nonsaline and permeable. It has good tilth, retains adequate moisture and contains no known toxic elements. Additional material requiring special placement is similar, but it is usually highly saline. However, the soluble salts will readily leach from material subjected to downward movement of natural precipitation.

Multiply feet by 0.3048 to obtain meters

T. 2 S. - R. 49 E.      T. 3 S. - R. 49 E.  
Section 34              Sections 2, 4, 8





**EXPLANATION**  
DEPTH OF TOPSOILING MATERIAL  
FOR USE ON OR NEAR THE SURFACE

	0-0.5
	0.5-1.0
	1.0-1.5
	1.5-2.0
	2.0-2.5

TOTAL DEPTH OF TOPSOILING AND ACCEPTABLE SURFACE MATERIAL (2)

**NOTES**

Topsoiling material, as used in this report includes that portion of the overburden (soil mantle and bedrock) that is capable of sustained plant production. The material for use on or near the surface is nonsaline and permeable. It has good tilth, retains adequate moisture and contains no known toxic elements. Additional material requiring special placement is similar, but it is usually highly saline. However, the soluble salts will readily leach from material subjected to downward movement of natural precipitation.

Multiply feet by 0.3048 to obtain meters.

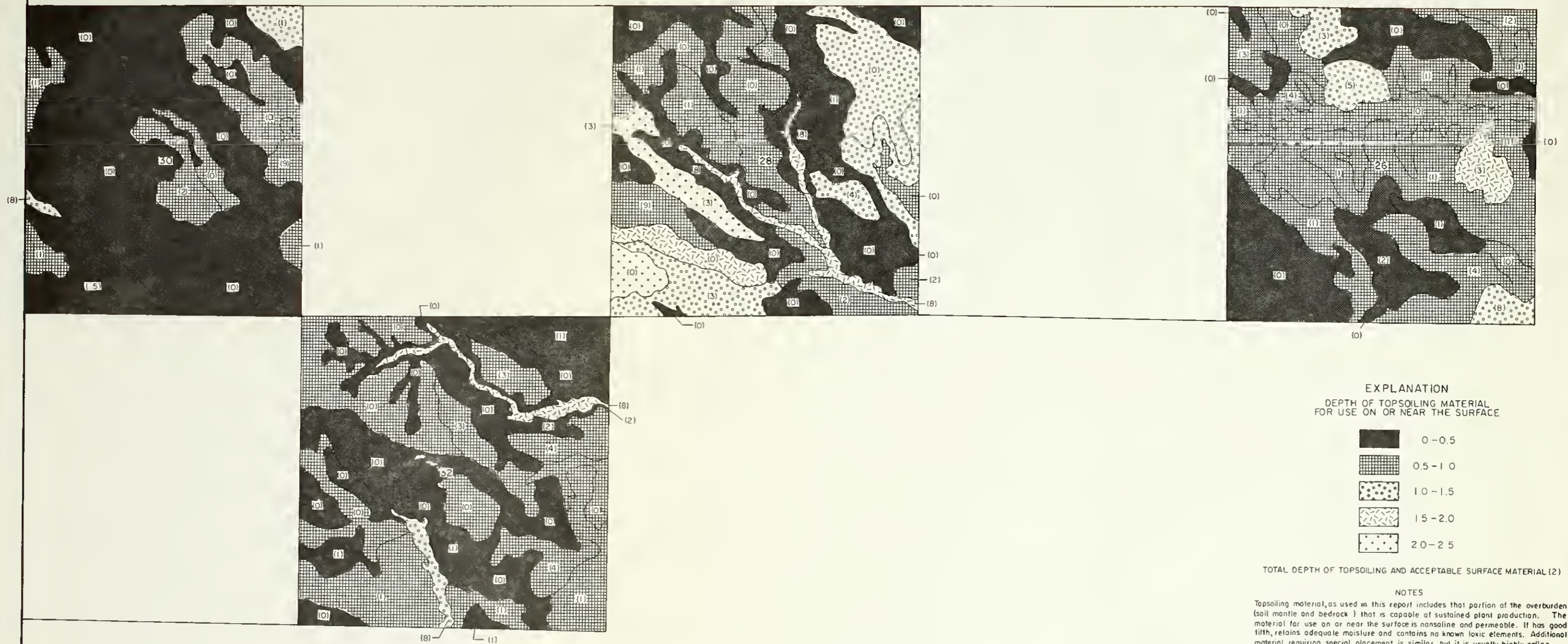
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T. 3 S. - R. 49 E.  
Sections 14, 18, 20, 22

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION	
RESOURCE & POTENTIAL RECLAMATION EVALUATION	
PUMPKIN CREEK COALFIELD-MONTANA PUMPKIN CREEK STUDY AREA	
<b>TOPSOILING MATERIAL</b>	
CLASSIFIED <u>T. FIECHTEL</u>	SUBMITTED <u>                    </u>
DRAWN <u>L. E. ALLSOP</u>	RECOMMENDED <u>                    </u>
CHECKED <u>                    </u>	APPROVED <u>                    </u>
BILLINGS, MONTANA SHEET 3 OF 4	OCTOBER, 1978 1305-600-233





T. 3 S.-R. 49 E.  
 Sections 26, 28, 30, 32



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UNITED STATES  
 DEPARTMENT OF THE INTERIOR  
 BUREAU OF RECLAMATION

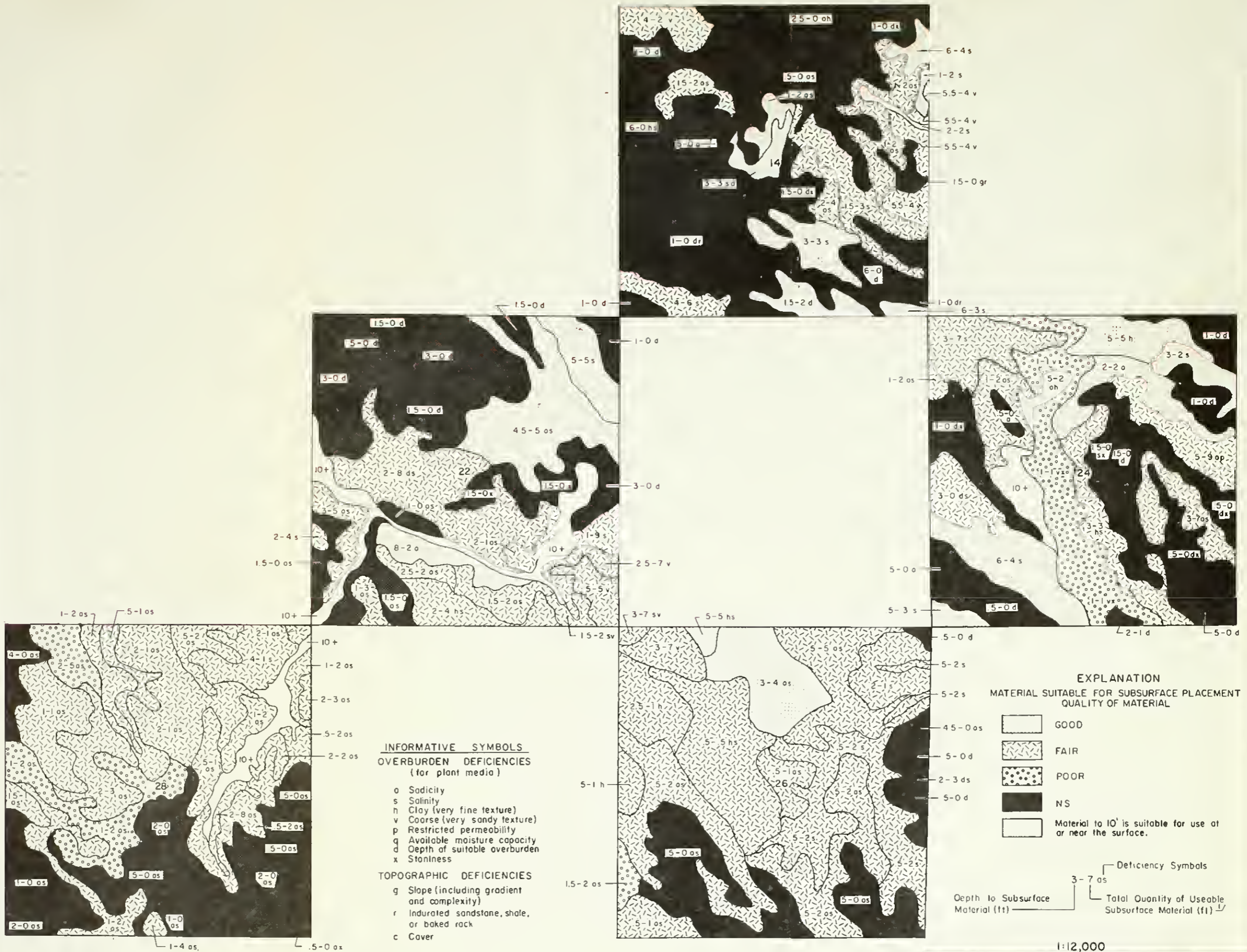
RESOURCE & POTENTIAL RECLAMATION EVALUATION  
 PUMPKIN CREEK COALFIELD-MONTANA  
 PUMPKIN CREEK STUDY AREA

**TOPSOILING MATERIAL**

CLASSIFIED	1. FIELD	SUBMITTED
DRAWN	L. E. ALLSOP	RECOMMENDED
CHECKED		APPROVED

BILLINGS, MONTANA OCTOBER, 1978 SHEET 4 OF 4 1305-600-234





NOTES

Usable material for subsurface, as used in this report includes that portion of the overburden (soil mantle and bedrock) that should be placed below the primary plant root zone in reconstructed profiles. It contains no known toxic elements but may be clayey, sandy or highly saline. However, the soluble salts will leach from material subjected to downward movement of natural precipitation.

Unless modified by leaching, mixing or other measures.

Multiply feet by 0.3048 to obtain meters.

T. 2 S. R. 49 E.  
Sections 14, 22, 24, 26, 28



1:12,000

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION  
PUMPKIN CREEK COALFIELD - MONTANA  
PUMPKIN CREEK STUDY AREA

**SUBSURFACE MATERIAL**

CLASSIFIED: T. FICHTL  
DRAWN: L. E. ALLSOP  
CHECKED: \_\_\_\_\_

SUBMITTED: \_\_\_\_\_  
RECOMMENDED: \_\_\_\_\_  
APPROVED: \_\_\_\_\_

BILLINGS, MONTANA  
OCTOBER, 1978  
SHEET 1 OF 4

1305-600-235



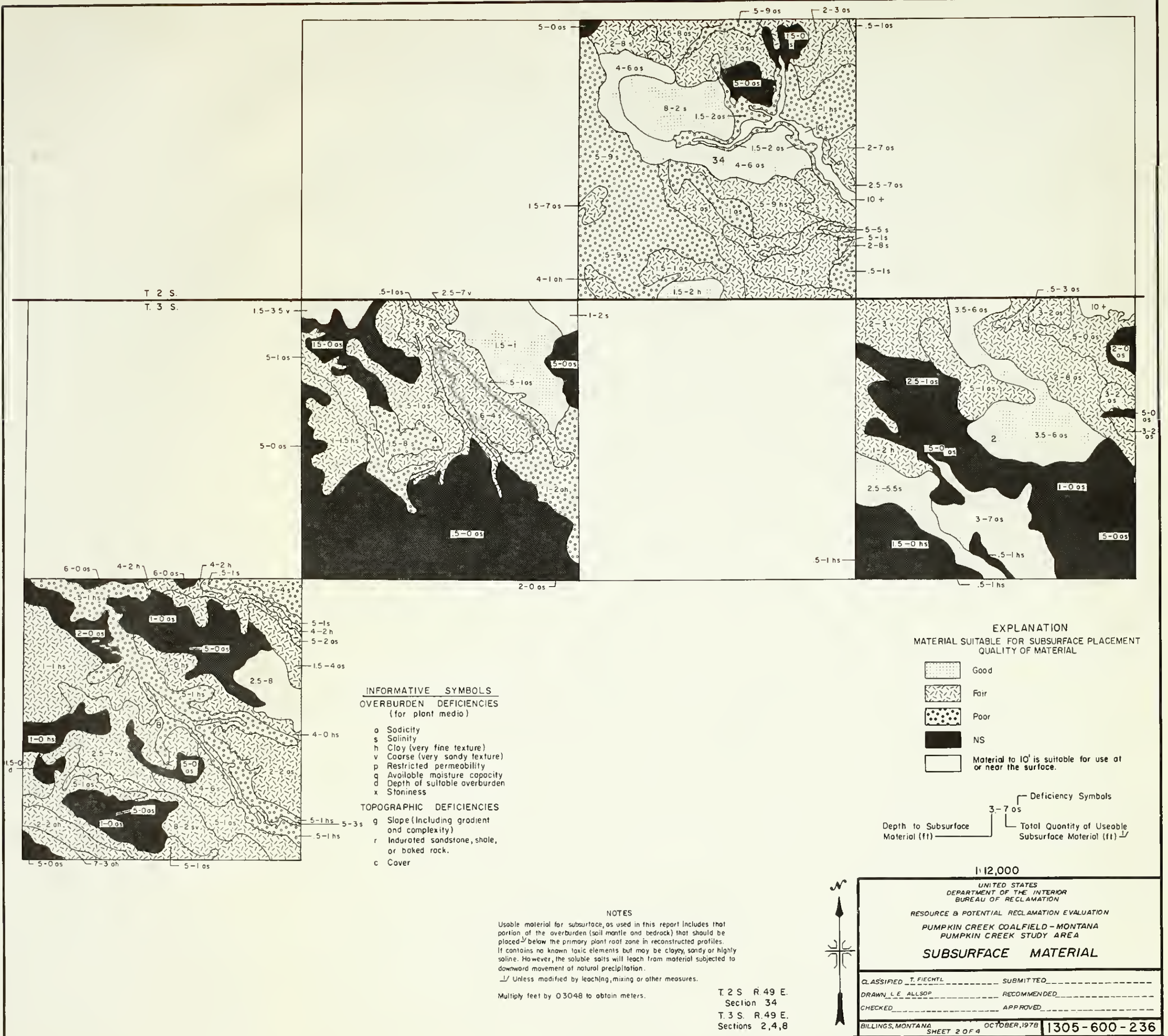








Table 24

LAND SUITABILITY SPECIFICATIONS - SURFACE MINE RECLAMATION  
Suitability of Overburden for Revegetation of Surface-Mined Areas  
BLM/WPRS Cooperative Program EMRIA  
Pumpkin Creek Study Area

United States  
Dept. of the Interior  
Water and Power  
Resources Service  
July, 1976

Overburden Characteristics	Symbols		Class 1	Class 2	Class 3
	Basic Information	Subclass and Deficiencies			
<u>SOILS AND/OR BEDROCK</u>	s				
<u>Textures</u>			Fine sandy loams to clay loams	Sandy loam to silty clay loams	Loamy sand to clay
<u>Coarse</u>	v			Sandy loams sufficiently coarse to slightly reduce productivity, moisture retention and may increase erosiveness slightly	Loamy sand in sufficient quantity to moderately reduce productivity, moisture retention, and may increase erosiveness moderately
<u>Fine</u>	h			Profile should have sufficient material for topdressing, clayey type materials that are slowly permeable should be placed below 6" in the reconstructed profile	Profile should have sufficient material for topdressing, placement of clay in reconstructed profile; permeable 10" plus; slowly permeable 30" plus
<u>Depth</u>	d		> 36" of overburden that is suitable for plant media	>18" of overburden that is suitable for plant media	>10" of overburden that is suitable for plant media
<u>Sodicity</u>	a		SAR not to exceed 9.0 in fine textured soils but may be 20.0 with loamy sand textures. Values can be slightly higher if compensated by adequate residual gypsum.		
<u>Salinity</u> (ECx10 <sub>3</sub> )	s		Less than 4	Less than 8 but should have 10" of material of less than 4 for surface	Less than 12 but should have 10" of material of less than 4 for surface
<u>Available Water Holding Capacity</u>	q		> 1.5"/foot of soil	>1.0"/foot of soil	> 0.75"/foot of soil
<u>Hydraulic Conductivity</u>	p		Adequate to provide a well drained and aerated root zone and an infiltration rate adequate to prevent serious erosion	Slightly restricted which may result in some restriction of drainage and aeration in the root zone and a reduced infiltration rate	Restricted to the extent that internal drainage may limit choice of vegetation and require special practices to control erosion
<u>Cobble and Stones</u> (> 3")	x		Less than 5% in soil mass	Less than 10% in soil mass	Less than 20% in soil mass
<u>Weatherability</u> <sup>1/</sup>			Will break down readily upon exposure to the weather	May require short period to break down upon exposure	May require extended period to break down
<u>Erodibility</u>			Susceptible to slight erosion	Susceptible to moderate erosion	Susceptible to severe erosion but can be controlled with proper management and placement
<u>TOPOGRAPHY</u> <sup>2/</sup>	t				
<u>Slope</u>	g		Permissible surface gradient 0 to 12 with smooth slopes	Permissible surface gradient 0 - 20%	Permissible surface gradient 0 - 35%
<u>Indurated Sandstone</u> Massive and lenticular	r		None	1 to 5% of area	5 to 20% of area
<u>Cover</u>	c		Not applicable		
<u>DRAINAGE</u>	d		Because of anticipated land alterations by surface mining, present drainage conditions, except the hydraulic conductivity of the material, are not a factor in the classification.		

Class 6 Areas delineated in this class generally lack suitable material for stripping and stockpiling as surface material. One or a combination of the following deficiencies may result in the use of this class: (1) insufficient surface soil and bedrock of suitable quality at or near the surface; (2) topography which prevents stripping including excessive slopes; (3) rocklands with large amounts of massive indurated surface sandstone; (4) toxic overburden (soil and bedrock), on or near the surface. Reclamation of lands will require material from outside the delineated area, from deep geologic strata or treatment of the available material.

<sup>1/</sup> Applicable only to bedrock material.

<sup>2/</sup> Not applicable to bedrock material.



Table 25 Description of Land Classes

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
1	14.1	<p>Land in this class has an average minimum depth of 36 inches of good or high quality overburden that is suitable for plant media. Usually this material is dark colored soil that has formed on deep alluvial, colluvial, and residual material. Medium texture is most common.</p> <p>Soil aggregates of these medium textured soils have moderate to good stability and water enters the material readily. Internal permeability is moderate and adequate moisture is retained for plant growth. This rate of water movement provides adequate aeration of the plant root zone.</p> <p>Soil material in this class is high in organic matter, nonsaline and nonsodic and there is no indication of toxic material. Below 24 inches the material is moderately calcareous.</p> <p>These lands usually have surplus high quality overburden that is suitable for topdressing or subsoil placement. This material when borrowed will enhance productivity of other tracts.</p>	<p>The surface relief comprises nearly level to gently sloping terraces, fans, foot slopes, and undulating uplands. Most of this land produces small grains and native range. Topographic features will not hinder stripping and stockpiling. Selective stripping can be accomplished easily. Native mid and short grasses are the most common range species.</p>	<p>These soils will be slightly susceptible to wind and water erosion but management practices such as vegetative mulch, mechanical roughing, or contour planting should be adequate control. For maximum use of soil in this land class, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum.</p>
2a	6.4	<p>Land in this class has an average minimum depth of 18 inches of fair and good quality overburden that is suitable for plant media. Usually this material is largely medium and moderately coarse textured soil that has formed deep colluvial and alluvial deposits and moderately deep residual soils. Textures range from sandy loams to clay loams. Good quality geologic material may be considered as part of the 18-inch requirement. Below 18 inches the overburden is usually calcareous. Soil limitations other than depth include: clay rich layers, reduced moisture retention, restricted permeability, and layers that are saline and sodic.</p> <p>Soil aggregates of these dark colored soils have fair to good stability and water enters the material at a moderate rate. The internal water movement is adequate to provide aeration of the primary plant root zone. Also, adequate moisture is retained for plant use. The material that is suitable for use at or near the surface is nonsaline and nonsodic and there is no indication of toxicity.</p>	<p>The surface relief comprises nearly level to rolling foot slopes, side slopes, swales, and undulating uplands. Topographic features will not hinder stripping and stockpiling desirable material; also, selective stripping can be accomplished easily. Native mid and short grasses are the most common range species. Small grains are the principal dry farmed crops.</p>	<p>Selection of suitable material for use at or near the surface will require a review of the field data. There is adequate topdressing material, but care must be exercised in selecting nonsaline permeable material for the subsoil and substratum. Selective stripping and stockpiling to isolate subsurface material followed by selective placement is necessary for the best use of available material in this land class.</p> <p>With proper selection and placement, reclamation should not be difficult and average management should assure successful permanent revegetation.</p>

Table 25 Description of Land Classes

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
2t	7.1	<p>Land in this class has an average minimum depth of 36 inches of good and high quality overburden that is suitable for plant media. Usually this material is dark colored soil that has formed on deep alluvial, colluvial, and residual material. Medium texture is most common.</p> <p>Soil aggregates of these medium textured soils have moderate to good stability and water enters the material readily. Internal permeability is moderate and adequate moisture is retained for plant growth. This rate of water movement provides adequate aeration of the plant root zone.</p> <p>Soil material in this class is high in organic matter, nonsaline and nonsodic and there is no indication of toxic material. Below 24 inches the material is moderately calcareous.</p> <p>These lands usually have surplus high quality overburden that is suitable for topdressing or subsoil placement. This material when borrowed will enhance productivity of other tracts.</p>	<p>The surface relief comprises strongly sloping side slopes. Selective stripping will be difficult.</p>	<p>These soils will be slightly susceptible to wind and water erosion but management practices such as vegetative mulch, mechanical roughing, or contour planting should be adequate control. For maximum use of soil in this land class, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum.</p>
2st	10.9	<p>The general description of overburden characteristics of Class 2s applies to this class. The most common soil limitations are depth of soil mantle and slowly permeable material in the subsoil and substratum. Also salinity and sodicity.</p>	<p>The surface relief comprises moderately sloping to rolling foot slopes and smooth, steep side slopes. Selective stripping will be difficult and some mixing of surface and subsoil material will occur.</p>	<p>A review of the field data to determine the effect of unavoidable mixing of surface and subsoil material is needed to determine best stripping depths. This will also be a guide for placement in a reconstructed profile. The last paragraph describing management of Class 2s applies to this class also.</p>

Table 25 Description of Land Classes

Class Subclass	Z of Area	Overburden Characteristics	Land Features	Management Requirements
3s	10.0	<p>Land in this class has an average minimum depth of 10 inches of fair to good quality overburden that is suitable for plant media. Usually this material is largely medium to moderately fine textured soil that has formed on alluvial, colluvial, and residual deposits. The principal limiting soil factor is the limited quantity of nonsaline and nonsodic material for use at or near the surface. The subsoil and substratum often contain moderate to high amounts of sodium and large amounts of gypsum. They are saline and sodic. Laboratory tests indicated fair to poor permeability.</p> <p>Land in this class retains a large quantity of water for plant use. The infiltration rate and internal water movement are moderately slow.</p>	<p>The surface relief comprises nearly level alluvial terraces and adjacent foot slopes. Topographic features will not hinder stripping and stockpiling desirable material and selective stripping can be accomplished easily. Native mid and short grasses are the most common range species. Some tracts produce mixed grass hay and a few poorly drained tracts grow only salt grass.</p>	<p>For best use of the soil in this class, the surface material must be stripped and stockpiled, and the subsoil and substratum should be placed with the spoil material. Pitting or gouging basins will retard erosion and promote leaching of soluble salts below the primary root zone. Mulches can also be used to reduce erosion. These measures can increase the effective leaching of soluble salts and increase production capability. Successful permanent revegetation can be accomplished, but above average planning and management will be required.</p>

Table 25 Description of Land Classes

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
3t	2.7	<p>Land in this class has an average of 30 inches of good and high quality overburden that is suitable for plant media. Usually this material is dark colored soil that has formed on deep alluvial, colluvial, and residual material. Medium textures are most common.</p> <p>Soil material in this class is nonsaline, non-sodic, and moderately high in organic matter. There is no indication of toxic material. The subsurface material below 24 inches is moderately calcareous. Soil aggregates of these soils have moderate to good stability, allowing water to enter the surface layers readily. Internal permeability is moderate to moderately slow and adequate moisture is retained for plant growth. The rate of water movement provides adequate aeration of the plant root zone.</p> <p>These lands are a good source of quality overburden that is suitable for topdressing or subsurface placement. This material, when borrowed, will enhance the productivity of other tracts.</p>	<p>The surface relief comprises moderately steep, complex side slopes and crests. Selective stripping will be difficult.</p>	<p>These soils will be moderately susceptible to wind and water erosion, but management practices such as vegetative mulching, mechanical roughing, or contour planting should provide adequate control. For maximum use of soil in this land class, the upper 6-24 inches of surplus material should be stripped and stockpiled separately from the subsoil and substratum.</p>
3at	13.3	<p>Land in this class has an average minimum depth of 10 inches of fair to good quality overburden that is suitable for plant media. Usually this material consists of medium and moderately fine residual soil and/or weathered shale parent material. The major soil limitation is quantity of nonsaline and nonsodic material. There is adequate suitable material for revegetation for rangeland. Extensive borrowing of material would be required for profiles suitable for dryland farming.</p> <p>Locally the geologic material is permeable and the soluble salts can be leached. Some clay rich and sodium affected layers will most likely be included in the stockpiled material but this should be held to a minimum.</p>	<p>The surface relief of land in this class is characterized by strongly sloping foot slopes, moderately steep side slopes, and crests on hilly upland areas. Moderately steep slopes will make selective stripping difficult. Native mid and short grasses are the dominant species. This land is used for range.</p>	<p>Selective stripping with emphasis on stripping small tracts of deep soil separately should be considered. In addition to a review of the data, a field check to locate these tracts is advisable. Similar surface treatment of reconstructed profiles as described in 3s should be followed.</p>

Table 25 Description of Land Classes

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
6s	1.7	Land in this class has less than 10 inches average depth of fair and good quality overburden that is suitable for plant media. These soils have formed on old alluvium and residuum. This material is clay rich below the surface layer and is often highly saline and/or sodium affected. One or a combination of the above factors make these soils unsuitable for plant media. Some small tracts with good quality soil occur in this class as inclusions.	The surface relief in this class comprises nearly level to very gently sloping old alluvial terraces and residual foot slopes and benches. Topographic features will not hinder selective stripping and stockpiling. Native mid and short grasses are the dominant range species.	A careful review of the data and field checking to locate the small inclusions of better soil is warranted. This combined with selective stripping can do much to reduce the amount of overburden that must be borrowed or modified. Temporary irrigation, pitting, and leaching basins to increase leaching may adequately modify some material. However, borrowing from nearby deep good quality soil areas will probably be the most economical method of permanent revegetation.
6t	0.6	Land in this class has an average minimum depth of 36 inches of good and high quality overburden that is suitable for plant media. Soils in this class have formed on deep alluvial, colluvial, and residual material. They are usually dark colored and moderately high in organic matter. Textures are commonly medium and moderately fine.  These soils are nonsaline, nonsodic, and moderately calcareous below a depth of 24 inches. Aggregate stability is moderate to good in these soils, and water readily infiltrates the surface. Internal permeability is moderate to moderately slow, and adequate moisture is retained for plant growth. The rate of water movement provides adequate aeration of the plant zone.  Where accessible, the soils from this land class will provide good quality material suitable for topdressing or subsurface placement.	The surface relief comprises areas of complex, narrow bottom lands and drainage areas with steep side slopes below ridge crests. The dendritic drainage pattern creates complex slopes that prevent uniform selective stripping.  Active erosion may expose sandstone or shale in up to 25 percent of any designated area.  Native mid and tall grasses grow in association with forbs, sedges, and big and silver sage. This land class is used for range.	These soils will be highly susceptible to wind and water erosion. Management practices such as vegetative mulching, mechanical roughing, or contour planting will retard soil erosion.  For maximum use of soil in this land class, the upper 6 to 24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum.

Table 25 Description of Land Classes

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
6st	33.2	<p>Land in this class has less than 10 inches average depth of fair and good quality overburden that is suitable for plant media. These shallow residual soils have formed over weathered shale. Sandstone and shale outcrops are common.</p> <p>The underlying substratum is highly variable in physical and chemical properties. It may be highly saline, highly sodic, slowly permeable, or fine-textured (clay rich). These limitations occur singly or in combination in most areas delineated as Class 6st. Small inclusions of deeper soils and permeable, nonsaline, and nonsodic substratum material are common within these delineated areas.</p>	<p>The surface relief in this class comprises steep side slopes below ridge crests.</p> <p>Active erosion may expose sandstone or shale in up to 25 percent of any tract designated as Class 6st. The dendritic drainage pattern creates complex slopes that prevent uniform selective stripping.</p> <p>Native mid and tall grasses grow in association with forbs, sedges, and big and silver sage.</p> <p>This land class is used for range.</p>	<p>Tracts with deeper soils and suitable geologic material, though small, should be selectively stripped.</p> <p>Mechanical roughing of the surface will increase infiltration and enhance leaching of soluble salts. Vegetative mulching, contour planting, and the use of stabilizing structures will aid in reducing erosion.</p> <p>Borrow material will be required for successful permanent revegetation. The postmining soil profile and vegetative cover will likely be an improvement over present conditions.</p>

Table 26 - Results of the Land Suitability Survey  
Pumpkin Creek Study Area

[illegible]



This land suitability survey provides baseline data for assessing reclamation potential. It does not, however, provide adequate detail for stripping and stockpiling procedures during the surface mining operation. Additional field borings and observations supported by laboratory data will be necessary to more accurately determine the quantity, quality, and location of available material to be stripped and stockpiled for use as revegetative media.

### Overburden Suitability for Revegetation

#### Soil Mantle Suitability

Based on the field and laboratory data obtained from the land suitability survey, it appears that most of the residual, transported (alluvial/colluvial), and alluvial valley floor soils in this study area should yield about 6 to 12 inches of fair to good quality topsoiling material (Plates 33 through 36). This material, which usually includes the A and B horizons, is typically nonsaline, nonsodic, and moderately permeable. Because the A horizon of most soils in the study area is only 2 to 6 inches thick, selective stripping of this horizon from the B horizon appears impractical. However, mixing of the A and B horizons should not appreciably change the physical and chemical properties of the material.

Many of the soil profiles showed a moderate to strong increase in soluble salts, exchangeable sodium, and/or clay content below 12 to 18 inches in depth (C horizons). Therefore, a significant percentage of the available subsurface materials in this study area were classified as fair or poor for placement below the primary root zone in reconstructed profiles (Plates 37 through 40).

Permeable material that is moderately saline ( $EC \times 10^3 < 12.0$ ) may be utilized in areas lacking good or fair quality subsurface material. This material should reclaim readily under natural leaching conditions if placed over spoils with good internal drainage characteristics. Sodic or clay-rich materials should be selectively placed well below the plant rooting zone in reconstructed profiles.

#### Bedrock Suitability

A systematic evaluation was made of the bedrock core materials described in Plates 6 through 15, Appendix B. The applicable portions of the land suitability specifications (Table 24) provided criteria for the evaluation of these materials.

Although similar criteria were used for both the land suitability survey and the bedrock core evaluation, different suitability classes were assigned to the core materials. These classes relate primarily to the quality of the bedrock materials for use as plant media in revegetation. The classes are "suitable," "limited suitability," and "unsuitable." The suitable class corresponds to Class 1 and the higher quality Class 2 materials in the land suitability survey; the limited suitability class includes the lower quality Class 2 materials and Class 3; and the unsuitable class is equivalent to Class 6.

Bedrock samples were collected and analyzed in the laboratory utilizing the same procedures used to analyze the soil samples. Results of the laboratory analyses performed on the core samples are listed in Tables 27 through 36, Appendix D. These data include determinations of selected trace metal concentrations, which may be particularly useful in identifying bedrock materials which are potentially toxic or deficient in various elements.

The results of the laboratory analyses, along with the interpretations of the core profile descriptions, provided the basic data used in classifying the bedrock materials as to their suitability for use as plant media. The suitability of bedrock materials is indicated in Table 37, Appendix D, and on each geologic log diagram, Plates 6 through 15, Appendix B, under the column titled: "Suitability for Reconstructed Profile." Overall, approximately 3 percent of the bedrock materials overlying the Sawyer/A Coalbed in this study were determined to be suitable for use as plant media; 14 percent were of limited suitability; and 83 percent were classed as unsuitable. 2/

Because the type and quality of bedrock materials are quite diverse, the physical and chemical properties important to their use as plant media cannot be projected accurately over a wide range of conditions. Therefore, the quality determination of the bedrock materials applies only to the specific site where each core was drilled. No attempt was made to project the data to adjacent areas. Also, the ease of separating and stockpiling bedrock materials for resurfacing was not a factor in the classification.

Although the consolidated bedrock in the Pumpkin Creek Study Area should break down readily upon weathering, it is generally unsuited for use as revegetative media at or near the surface in reconstructed profiles. Notable deficiencies of the bedrock materials often include one or more of the following: fine texture (i.e., shale), salinity, sodicity, slow permeability, and erodibility.

### Soil Inventory

This section provides additional information on the soils occurring in the Pumpkin Creek Study Area. Most of the information is derived from soil survey data compiled by the Soil Conservation Service. 3/

Data presented in this section include the following:

1. Soil Inventory maps of the Pumpkin Creek Study Area showing the soil types/complexes/associations mapped by the Soil Conservation Service - Plates 41 through 45, Appendix D.

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2/ Coalbeds greater than 1 foot thick, which overlies the Sawyer/A Coalbed, were not included in the bedrock suitability determination.

3/ Soil survey of the Powder River Area, Montana, USDA - Soil Conservation Service, 1971.

2. Soil series descriptions (National Cooperative Soil Survey) - Tables 38 through 60, Appendix D (Note - A number of soil series names originally listed in the 1971 Soil Survey Report have been updated by SCS based on additional data; however, this report contains only the original soil series as listed in the 1971 report).

3. Interpretive ratings for selected soil uses - Table 61, Appendix D.

4. Engineering properties of the soils - Table 62, Appendix D.

5. Erosion Evaluations (BLM Form 7310-12) Correlating with USBR Point Site Soil Profile Descriptions - Exhibit 3, Appendix D.

## GREENHOUSE EVALUATION OF OVERBURDEN MATERIALS 1/

In the past, surface mining for coal has generally resulted in soil material being buried beneath a mixture of spoils. Spoils exposed at the surface often originated from bedrock strata directly overlying the coal seam, resulting in a poor quality plant medium. In many cases, this has led to a severe problem in revegetation of surface-mined lands.

Montana law now requires that: "All available topsoil shall be removed from the area of land affected before further disturbance occurs." /Rule VIII(1) pursuant to the Montana Strip and Underground Mining Act, 1980/. If the mine operator proposes to use subsoil or bedrock material in place of or along with topsoil, he must: (1) document problems of topsoil quantity or quality, and (2) demonstrate to the Montana Department of State Lands that the selected overburden materials to be used are equally or more suitable for restoring land capability and productivity.

The objectives of this greenhouse study were to:

1. Characterize soil and bedrock materials as plant growth media in relation to reclamation and revegetation of potential coal-mined areas, and

2. Conduct soil and plant analyses of selected materials for identifying potential problems relating to toxicity and/or nutrient deficiencies that may limit plant growth.

### Procedures

#### Soil Preparation

After the material was removed from the shipping bag, the material was mixed, and 100 grams were set aside for laboratory analysis. Two kilograms of the material were then placed in each of two plastic lined half-gallon round paper cartons and labeled in the following manner: each carton carried the number used by the Bureau of Reclamation for cataloguing purposes during recovery.

#### Field Capacity

A part of the sample was placed in a tube and water was added to wet the soil two-thirds to three-quarters of the way down the tube. At the end of the wetting period (48 hours) the top 3 cm of soil was discarded while the middle section was placed in a soil moisture can, leaving about 2-5 cm of wet soil at the bottom of the tube. The soil moisture cans which had been previously weighed were then weighed with the wet soil

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1/ This study was conducted by the Department of Agronomy, Colorado State University, Fort Collins, Colorado, for the Bureau of Reclamation, U.S. Department of the Interior under Contract No. 6-07-DR-50130 and Amendatory Agreement No. 1 to the same contract.

and placed in a forced air oven to dry at 100 degrees centigrade for at least 24 hours. They were then weighed again and percent field capacity was calculated by the formula:

$$\frac{(\text{Weight of can} + \text{wet soil}) - (\text{weight of can} + \text{dry soil})}{(\text{weight of can} + \text{dry soil})} \times 100 = \% \text{ field capacity.}$$

Field capacity was determined primarily to serve as a guide for ensuring proper water management in the greenhouse.

#### Fertilizer Treatment

Before planting, fertilizer application of 100 ppm of nitrogen as reagent grade  $\text{Ca}(\text{NO}_3)_2$  and 80 ppm of P as reagent grade  $\text{Ca}(\text{H}_2\text{PO}_4)_2$ , in five and fifty milliliter aliquots, respectively, was added to each pot. This was done along with the preplant watering. Before the fertilizer or water were added, 150 gms of soil was removed from each pot and saved to be placed back in the pot after the seeds were added. All except 100 ml of the total water was added 24 hours before planting.

#### Planting

The pots were planted with 40 seeds of western wheatgrass (Agropyron Smithii var. Arriba). The seeds were evenly spaced in the pots and covered with the 150 grams of soil that had been removed before fertilization took place. After smoothing the surface of the pot, the last 100 mls. of water was added and the pots were covered with brown paper to prevent evaporation. The pots were checked every day to assure that the topsoil remained moist. As the seeds started to germinate, the pot was uncovered so as to prevent the development of spindly plants. After 2½ weeks, or approximately 10 cm. height, the plants were counted and recorded for all pots, and then the pots were thinned to 16 plants and randomized. Pots were rotated 1/3 of the way around the table every 3rd to 4th day to assure that all pots were subject to the same lighting. The greenhouse lights were set to allow 15-16 hours of daylight.

#### Daily Management

All pots were weighed daily and brought to field capacity with distilled water. Nitrogen as reagent grade  $(\text{NH}_3)_2\text{SO}_4$  was added at the rate of 50 ppm 21 days after planting.

#### Harvest

The crop of wheatgrass was harvested approximately 50 days after planting. This procedure entailed cutting the plants at approximately 2 centimeters above the surface of the material, washing in a .1 N HCl acid bath, rinsing twice in distilled water, placing in paper bags and drying at 60 degrees centigrade for 48 hours. Before cutting, the plants were measured and average height was recorded. After drying in a forced air furnace, the plants were weighed to the nearest one hundredth of a gram. Selected samples were then prepared for laboratory analysis.

## Soil and Overburden Analysis

### Electrical Conductivity:

Determined on a 1:1 dilution by using a solu-bridge. Insufficient sample did not allow for obtaining a saturated extract, thus soluble salts were determined on a 1:1 dilution. For interpretative purposes, the electrical conductivity obtained from the 1:1 dilution was multiplied by a factor of 2 to reflect the approximate EC of a saturation extract. The data, however, are reported for a 1:1 extract.

### Iron, Zinc, Copper and Manganese

Determined on the Atomic Absorption Spectrophotometer from a DTPA extract.

### pH

Determined with a combination electrode pH meter on a 1:1 dilution.

### SAR

Determined according to procedure in Agric. Handbook No. 60. The SAR reported is based on a 1:1 extract. For interpretation purposes, the SAR was converted using a calculation involving field capacity to approximate the SAR of the saturation extract.

### Extractable Phosphorus

Extracted with sodium bicarbonate and determined colorimetrically.

## Plant Tissue Analyses

Na, K, Ca, Mg, Fe, Zn, Mn and Cu were determined on the Atomic Absorption Spectrophotometer from a Perchloric Acid digest.

Phosphorus was extracted by the Bartons Reagent method and determined colorimetrically.

Note: Laboratory data is lacking for some materials because of insufficient sample and/or because of the lack of funding for carrying out all analyses.

### Criteria for Interpretation

The criteria as applied in this study are based on existing data used for evaluating soil-plant growth relationships on agronomic crops.

The use of these criteria was necessary due to the lack of information available for the soil-plant-climatic environments associated with mined lands in the areas under investigation.

The criteria used for evaluating salinity and sodium problems are thought to be very reliable. However, the limits defined for the other soil and plant chemical characteristics must be considered as being somewhat

arbitrary. They must be considered as a first approximation, using existing diagnostic data, in an attempt to identify and/or isolate potential problems associated with the growth of plants on these types of materials.

### Soil Diagnostic Criteria

The following criteria are based on current Colorado State University soil testing evaluation procedures.

#### Available P

- 0 to 3 ppm - very low
- 4 to 7 ppm - low
- 8 to 11 ppm - medium
- 11 + ppm - high

#### Available Zinc

- 0 to 0.5 ppm - very low
- 0.51 to .99 ppm - low
- 1.0 to 1.5 ppm - medium
- 1.5 + ppm - high

#### Available Iron

- 0 to 2.0 ppm - low
- 2.1 to 4.0 ppm - medium
- 4.0 + ppm - high

#### Available Copper and Maganese

- 0 to 0.5 ppm - low
- 0.5 + ppm - high

#### SAR

- 0 to 10 - - low sodium hazard
- 10 to 15 - - medium sodium hazard - potential problem
- 15 + - - high - very high probability that a sodium problem exists  
and will seriously affect reclamation potential

Note: The SAR values reported are based on a 1:1 extract. For interpretive purposes, the following conversion was made to approximate the SAR of a saturation extract. This procedure is not recommended

for common use. Saturation extracts were not used because of insufficient sample.

$$\text{SAR of Saturation Extract} = \sqrt{\frac{100}{\% \text{ Saturation at Field Capacity}}} \times \text{SAR of 1:1 Extract}$$

#### Salinity

- < 4 mmhos/cm electrical conductivity - low
- 4 to 8 mmhos/cm electrical conductivity - moderate salinity problem
- > 8 mmhos/cm electrical conductivity - high salinity problem

#### Plant Diagnostic Criteria

The following criteria are based on a general interpretation of existing plant analysis data. These criteria are presented here mainly to evaluate the relationship between soil test values and plant uptake data rather than as an indicator of a critical deficiency problem. The latter is not possible because of the lack of adequate data. No attempt has been made to identify toxicity levels.

<u>Total Phosphorus</u>		<u>Total Zinc</u>	
< 0.1%	critical	< 10.0 ppm	critical
.1-2.0%	marginal	10-20 ppm	marginal
> 2.0%	adequate	> 20 ppm	adequate

#### Total Copper

- < 5 ppm - potentially deficient
- 5-10 ppm - adequate
- > 10 ppm - for some plants, copper levels in excess of this amount may indicate a potential toxicity problem

#### Total Manganese

- < .2 ppm - potentially deficient
- > .2 ppm - adequate

#### Total Potassium

- 0 to 1.0% - potentially deficient
- 1.0 to 2.0% - intermediate
- > 2.0% - adequate

#### Total Calcium

- 0 to 0.25% - potentially deficient
- 0.25% or greater - adequate

### Total Magnesium

0 to 0.25% - potentially deficient

0.25% or greater - adequate

Note: In many cases, the selected criteria was made arbitrarily because the critical values for various stages of growth of western wheatgrass are not known. The selected ranges are used in this text as the reference level for comparing yield vs. plant vs. soil test data. The levels used must not be interpreted as being valid for making concrete interpretations. False conclusions will result if they are used as such.

### Studies Performed

1. A greenhouse study was conducted to determine the relative yield potential of western wheatgrass among the materials tested and to correlate yield response with soil and plant laboratory characterization data.
2. Pre-plant and post-harvest soil analyses for available P were conducted to determine the effect of added fertilizer on the soil availability index for P.

Soil characterization data are shown in Table 63, Appendix E. Plant analyses data are shown in Table 64, Appendix E. An interpretative summary and suitability ratings for all materials tested are shown in Table 65.

### Summary of Results

1. The initial available P level was low to very low in all materials except Sample No. T-2129, in which it was very high. The addition of 80 ppm P as fertilizer P raised the available P level to a very high level as reflected in Table 63, Appendix E. It appears that P will be a major limiting factor when considering the use of the materials as plant growth media.
2. Salinity and/or sodium appear to be the major limiting factors for most of the materials classed as unsuitable in Table 65.
3. The P levels seem to be very adequate in all western wheatgrass samples analyzed (see Table 64, Appendix E).
4. Iron, copper, and manganese levels are relatively high for western wheatgrass (see Table 64, Appendix E).

5. The plant analyses data indicate an important relationship among sodium, calcium and magnesium levels in the plant. Data in Table 66, Appendix E, indicate that with high soil sodium-low calcium levels, the uptake of sodium in the plants was high with subsequent low calcium and magnesium levels. It appears that this relationship exists not only for those materials having very high SAR values, but also in some cases with materials having moderate to even low SAR values. Statistical analysis of the data is required to aid in assessing whether the relationships observed are real. It does appear, however, that there may be a sodium, calcium and magnesium vs. yield relationship that is significant. This factor may not be significant in terms of its effect on successful revegetation but may be important from the standpoint of the nutrient quality of the forage grown on these materials.

6. The data obtained indicate a number of potential problems may exist for those materials classed as being "Questionable" in Table 65. In addition, factors other than those studied also may be limiting growth. Thus, it is recommended that additional characterization of these materials be carried out before they are considered as materials having potential for revegetation purposes.

7. The greenhouse data served as a useful tool in stratifying materials in terms of their productivity potential. This phase of the study appears to be very useful as part of a screenable testing program. The combined greenhouse and laboratory data are keys to identifying the nature and extent of the kinds of further evaluations that are needed.

## Interpretive Summary for all Pumpkin Creek Materials

Sample No.	Relative Yield Western Wheat %	Remarks	Suitability Rating
Control	100	--	--
T2117	114	No apparent problems.	Suitable
T2112	104	No apparent problems.	Suitable
T2114	100	No apparent problems.	Suitable
T2132	99	No apparent problems. Zn may have been deficient for corn crop.	Suitable
T2111	98	No apparent problems.	Suitable
T2080	91	K level may be adequate but is near questionable deficiency level.	Questionable to unsuitable
T2134	91	Electrical conductivity may be sufficiently high to present problems.	Questionable
T2136	89	Electrical conductivity may be sufficiently high to present problems.	Questionable to unsuitable
T2090	86	Electrical conductivity may be sufficiently high to present problems.	Questionable
T2086	84	Electrical conductivity may be sufficiently high to present problems.	Questionable
T2091	84	Extractable Mg was very low in this material. Zn soil level is marginal.	Questionable
		Field capacity is low. No serious salt crusting or soil surface cracking observed.	
T2098	80	Total Mg in plant tissue was .02%. Extractable Mg from soil was also low relative to other materials. Low field capacity.	Questionable
T2123	80	Extractable Mg in soil was low. No plant analysis data was obtained. Except for this factor, there was no indication of any potential problem.	Questionable
T2130	80	(Same as for T2123)	Questionable
T2079	78	Zn level in corn was marginal. Mg level in western wheatgrass was low relative to other samples.	Questionable
T2096	77	Salinity is the most obvious limiting factor. Salt crusting occurred.	Unsuitable
		No plant analysis data available.	
T2092	76	Zn is potentially limiting to corn. Reflected both in soil and plant analysis data.	Unsuitable
		Zn level in western wheatgrass is in upper marginal zone. Soil extractable Mg is low relative to other materials. Severe surface cracking noted on this material. Low field capacity.	Unsuitable
T2115	75	Salinity is potentially limiting.	Questionable
T2133	75	Zn level in both corn and western wheatgrass was in marginal zone. No sodium or salinity data available for material.	Questionable
T2113	74	Zn level in both corn and western wheatgrass is marginal. Ca and Mg levels in western wheatgrass are in potentially deficient range.	Questionable
T2093	71	Salinity is marginal. Field capacity low. Mg level in western wheatgrass is in potentially deficient zone.	Questionable
T2095	71	Salinity is sufficiently high to cause potential problems. Salt crusting was observed.	Questionable
76-101-3	71	Salinity may be a slight problem. Ca and Mg low in both western wheatgrass and corn.	Questionable
T2094	70	Salinity is sufficiently high to cause potential problems.	Questionable
T2105	68	Soil Zn level is low. No plant data available. Salinity only slightly above non-salinity range. SAR is high.	Unsuitable
T2129	67	SAR (recalculated) is marginally high. Ca and Mg levels in western wheatgrass are low relative to plants grown on other materials.	Questionable
76-101-14	67	SAR is high.	Unsuitable

Sample No.	Relative Yield Western Wheat	Remarks	Suitability Rating
T2118	66	Salinity is high. SAR is marginally high.	Unsuitable
T2089	65	Salinity is high. SAR is marginally high.	Unsuitable
76-101-13	65	SAR is very high.	Unsuitable
76-101-12	64	SAR is high.	Unsuitable
T2083	63	PH is very high. SAR is low. Salinity is low. Salt crusting was observed on pots. Ca, Mg and Zn levels in western wheatgrass were in marginally deficient range. Field Capacity low.	Questionable
T2131	63	Soil Zn and Mg low in soil. No real apparent problem.	Questionable
T2097	60	Salinity is high.	Unsuitable
T2085	59	Slight salt crusting observed in greenhouse. Existing data failed to indicate low yield response.	Questionable
T2100	59	SAR is marginal. No other limiting factor identifiable from data.	Questionable
T2128	59	SAR is high.	Unsuitable
T2088	57	Salinity and SAR high.	Unsuitable
T2116	57	Salinity is high.	Unsuitable
T2106	56	Salinity and SAR high.	Unsuitable
T2087	55	Salinity and SAR high.	Unsuitable
T2124	55	SAR high. Salinity marginal.	Unsuitable
76-101-15	55	SAR high.	Unsuitable
T2082	54	Extractable Mg low relative to other materials.	Questionable
T2125	54	SAR and salinity high.	Unsuitable
T2135	54	Salinity is moderately high. No SAR data available. pH does not suggest a sodium problem. Questionable to unsuitable	Unsuitable
T2099	53	High SAR.	Unsuitable
T2119	53	High salinity and SAR.	Unsuitable
T2121	52	High salinity and SAR.	Unsuitable
T2122	52	Moderately high salinity; very low Zn level in soil. Marginal Zinc level in western wheatgrass and corn plants. Ca and Mg level below 0.5% in western wheatgrass.	Unsuitable
T2084	51	Salinity and SAR high.	Unsuitable
T2120	51	SAR high.	Unsuitable
T2101	50	Salinity and SAR high.	Unsuitable
T2127	47	Salinity and SAR high.	Unsuitable
T2126	46	Salinity and SAR high.	Unsuitable
T2103	44	Salinity and SAR high.	Unsuitable
T2081	41	Extractable Zn low. Extractable K potentially low. Extractable Mg very low relative to other materials.	Questionable
76-101-11	37	SAR high; salinity marginally high.	Unsuitable
T2109	36	Salinity and SAR high.	Unsuitable
T2102	30	Salinity and SAR high.	Unsuitable
76-101-1	30	No evidence from existing data to explain low yield. SAR data not available.	Questionable to unsuitable
T2110	29	SAR high.	Unsuitable
76-101-4	27	Salinity moderately high. No SAR data available. pH does not indicate a sodium problem.	Unsuitable
76-101-2	26	Ca and Mg levels in western wheatgrass are low relative to plants grown on many other samples. pH does not indicate a sodium problem.	Unsuitable

Sample No.	Relative Yield Western Wheat	Remarks	Suitability Rating
T2107	24	High SAR and salinity.	Unsuitable
T2108	20	High SAR and salinity.	Unsuitable
T2104	19	High SAR	Unsuitable
76-101-7	18	High SAR	Unsuitable
76-101-9	17	High SAR and salinity.	Unsuitable
76-101-10	14	High SAR and moderate salinity.	Unsuitable
76-101-5	11	High SAR and salinity.	Unsuitable



## HYDROLOGY

### Introduction

A basic understanding of the hydrology is necessary to assess potential effects of mining on water resources and to suggest alternative solutions to water problems that may occur. This report describes the hydrologic testing, data collection, and data analysis after 1 year of intensive data collection in the vicinity of the Pumpkin Creek Study Area. The report is the first phase of a continuing study to determine baseline hydrologic conditions in the study area.

The water resources investigation described in this report encompasses the East Pumpkin Creek Coalfield (Figure 4). A topographic divide between tributaries forms an arbitrary southern boundary to the study area for the water resources investigation. Streamflow and water quality data have been collected on bordering streams since November 1975. Stock reservoirs in the study area were inventoried from aerial photographs and field inspections to determine relative storage capacities and water quality. In addition, average sediment yield to a reservoir from an upland drainage subbasin was estimated by indirect methods in the spring of 1977.

Ground water data were collected from existing wells and springs inventoried during the summers of 1976 and 1977 and from 11 test wells drilled by the Geological Survey in the autumn of 1976. <sup>1/</sup> Hydrologic boundaries and properties of shallow aquifers, principal direction of water movement, and water chemistry were determined from the data.

Further study will include long-term hydrologic monitoring to obtain a better understanding of the hydrologic system in the study area. More testing would be necessary if a detailed model were to be constructed to quantitatively analyze water problems that could occur from specific mine plans.

### System for Describing Geographic Locations

Wells and sites described in this report are specified by location according to the General Land Office system of land subdivision. The first three characters of the location code specify the township south, S, of the Montana base line; the next three, the range east, E, of the Montana principal meridian. The next two characters specify the section number within the township. The final four letters specify the location within the quarter section (160-acre tract), the quarter-quarter section (40-acre tract), the quarter-quarter-quarter section (10-acre tract), and the quarter-quarter-quarter-quarter section (2½-acre tract). Subdivisions of a section are designated A, B, C, and D in a counter-clockwise direction, beginning in the northeast quadrant. If more than one feature is located in a 2½-acre tract, consecutive digits are added to the end of the location number in order of inventory. For example, a well numbered 02S49E22DCCA2 would be the second well described in the NE¼ of the SW¼ of the SW¼ of the SE¼ of Section 22, Township 2 South, Range 49 East (Figure 5).

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<sup>1/</sup> Lithologic logs of drill holes for test wells are included as Exhibit 5 in Appendix F.

## Surface Water

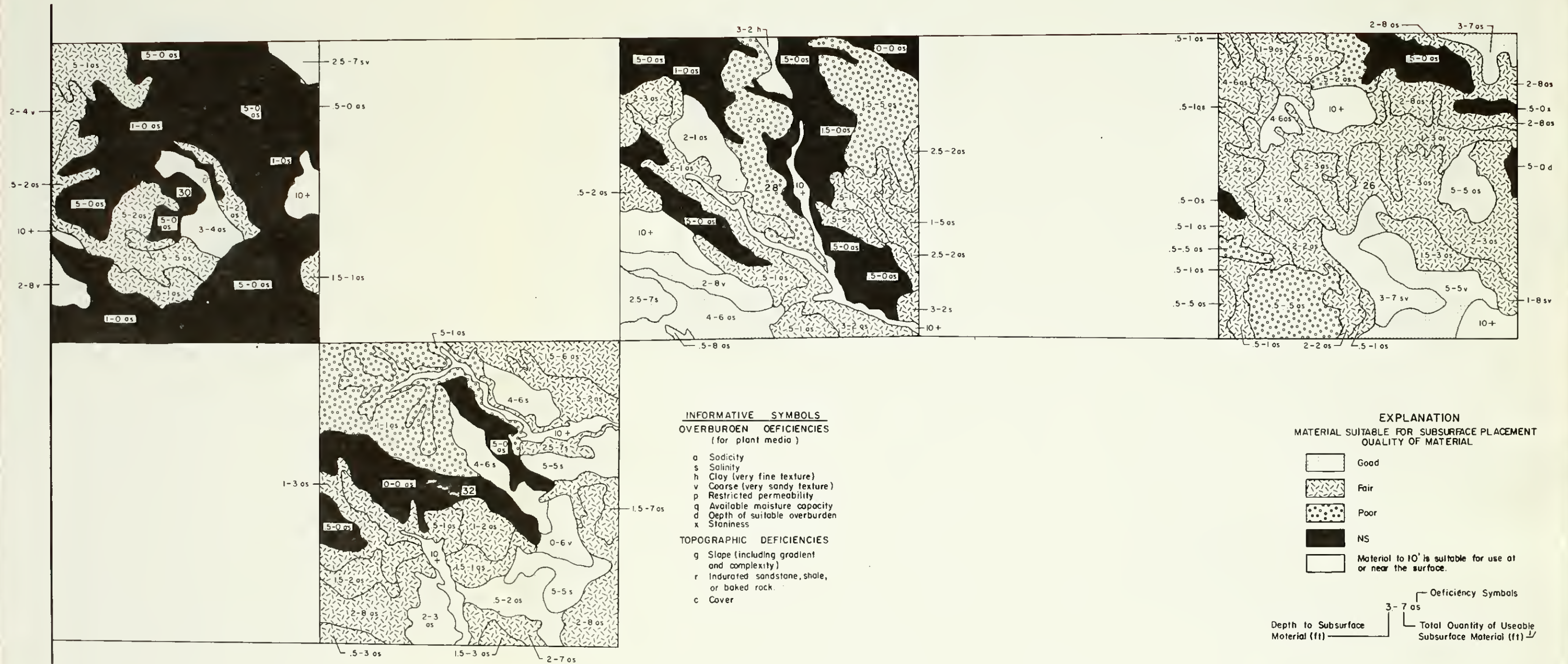
The study area for the water resources investigation lies along the drainage divide between northward-flowing Pumpkin and Mizpah Creeks. The gently sloping divide has been eroded by approximately parallel ephemeral tributaries to the Pumpkin and Mizpah Creeks. The tributaries flow northwestward on the west side of the divide and southeastward on the east side.

Direct runoff within the study area can be highly variable: it is controlled largely by seasonal weather conditions, drainage slope and area, catchment stock reservoirs, and spreader irrigation. The general tributary geometry is V-shaped along the upper reaches, becoming U-shaped near Pumpkin and Mizpah Creeks. Evidence of gully erosion during periods of high runoff is common along reaches of these tributaries.

Peak discharges have not been measured for drainages within the study area. However, annual peak discharges have been determined by slope-area and peak-stage methods for the tributary of Sixmile Creek upstream from the culvert located at 03S48E36CCBC (Figure 4). For an effective drainage area of  $0.45 \text{ mi}^2$  (square miles), annual peak discharges have varied from 2 to  $74 \text{ ft}^3/\text{s}$  (cubic feet per second) since 1973 (Table 67). For comparison, flood discharges were estimated for upper parts of six drainage subbasins (Table 68 and Plate 46). Drainage area, main channel slope, and average annual precipitation were used to calculate the 2-year flood discharges, which range from  $7 \text{ ft}^3/\text{s}$  for small drainage areas to  $16 \text{ ft}^3/\text{s}$  for the largest. The 25-year flood discharges range from 81 to  $163 \text{ ft}^3/\text{s}$ . Runoff of this magnitude typically occurs during intense rainstorms, which seldom last more than 1 day.

Most surface water runoff is intercepted by stock reservoirs or irrigation spreader dikes before it reaches Pumpkin and Mizpah Creeks. Volume of runoff, evaporation rate, and reservoir leakage are the major factors controlling the storage potential of the reservoir. During years of normal precipitation, 43 of the 57 reservoirs inventoried in the study area are usually dry by late summer (Plate 46). The ephemeral reservoirs are generally less than 3 acres in surface area, have depths greater than 6 feet, and receive runoff from the upper reaches of the drainages. Most existing hayfield irrigation ditches and dikes are located in tributary valleys downstream from the coalfield.

Pumpkin and Mizpah Creeks flow intermittently in the vicinity of the study area. Data from water quality stations installed near the study area (Figure 4) indicated that streamflow is low and can be attributed mostly to local runoff and ground water discharge. Measured discharge did not exceed  $8.6 \text{ ft}^3/\text{s}$  during periods of spring runoff in 1976 and 1977 (Table 69, Appendix F). Slow melting of snowpack and the presence of numerous irrigation diversions and stock reservoirs along Pumpkin and Mizpah Creeks create low streamflow conditions at these stations. For instance, aerial photographs taken in 1974 show 13 small dams on Pumpkin Creek between the southwesternmost tributary of the study area and the station Pumpkin Creek near Loesch (Figure 4). Although no measurements have been made at these sites during intense rainstorms, indirect methods of flow determinations indicate that no high flows have occurred since



## NOTES

Usable material for subsurface, as used in this report includes that portion of the overburden (soil mantle and bedrock) that should be placed below the primary plant root zone in reconstructed profiles. It contains no known toxic elements but may be clayey, sandy or highly saline. However, the soluble salts will leach from material subjected to downward movement of natural precipitation.

Unless modified by leaching, mixing or other measures

Multiply feet by 0.3048 to obtain meters.

T. 3 S. R. 49 E.  
 Sections 26, 28, 30, 32

1:12,000  
 UNITED STATES  
 DEPARTMENT OF THE INTERIOR  
 BUREAU OF RECLAMATION  
 RESOURCE & POTENTIAL RECLAMATION EVALUATION  
 PUMPKIN CREEK COALFIELD - MONTANA  
 PUMPKIN CREEK STUDY AREA

## SUBSURFACE MATERIAL

CLASSIFIED BY T. FIECHT  
 DRAWN BY L. ALLSOP  
 CHECKED BY  
 SUBMITTED BY  
 RECOMMENDED BY  
 APPROVED BY  
 BILLINGS, MONTANA SHEET 4 OF 4 OCTOBER, 1978 1305-600-238



Figure 4

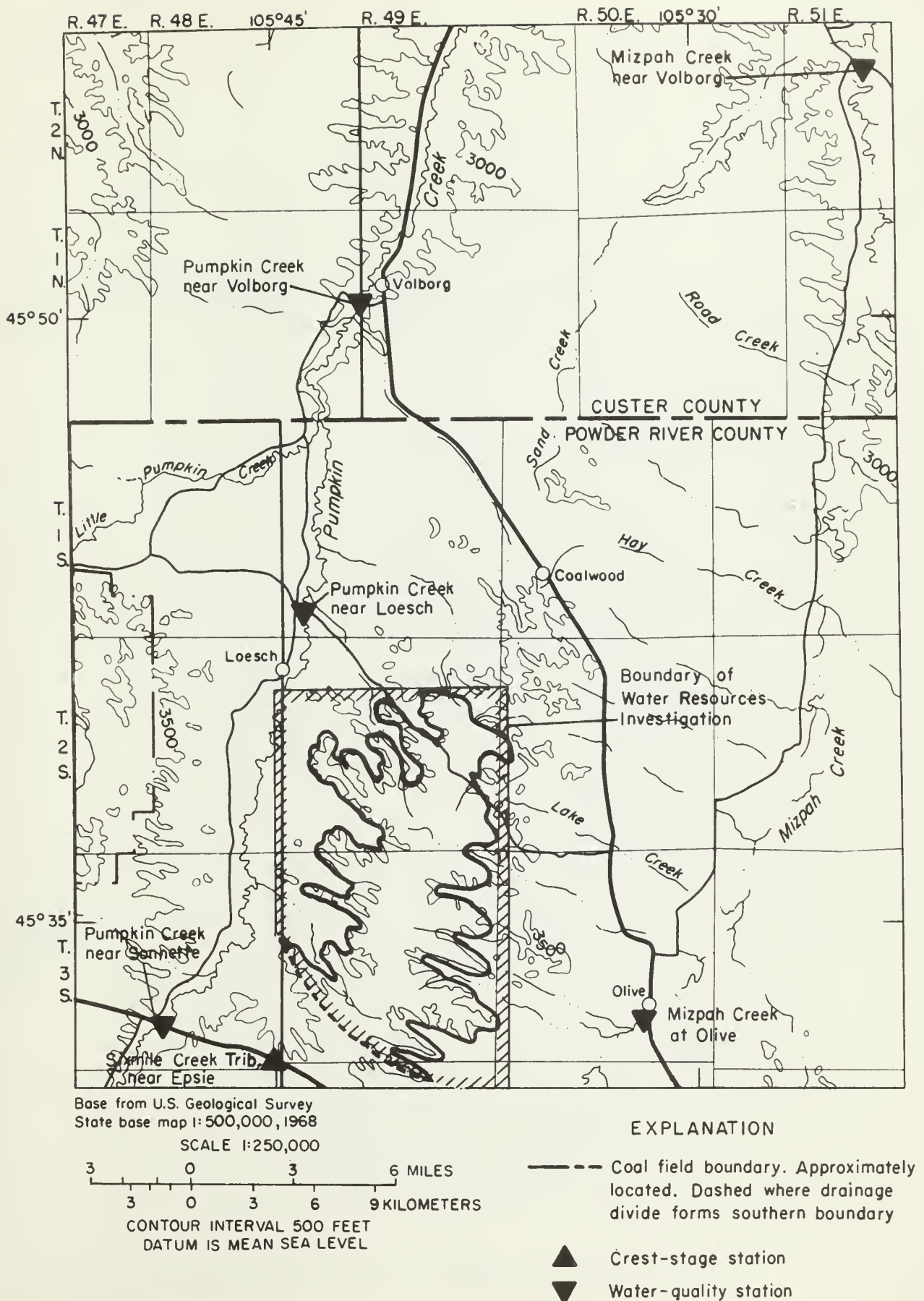


Figure 4 --Location of East Pumpkin Creek coal field and selected water-quality and crest-stage stations.



Figure 5

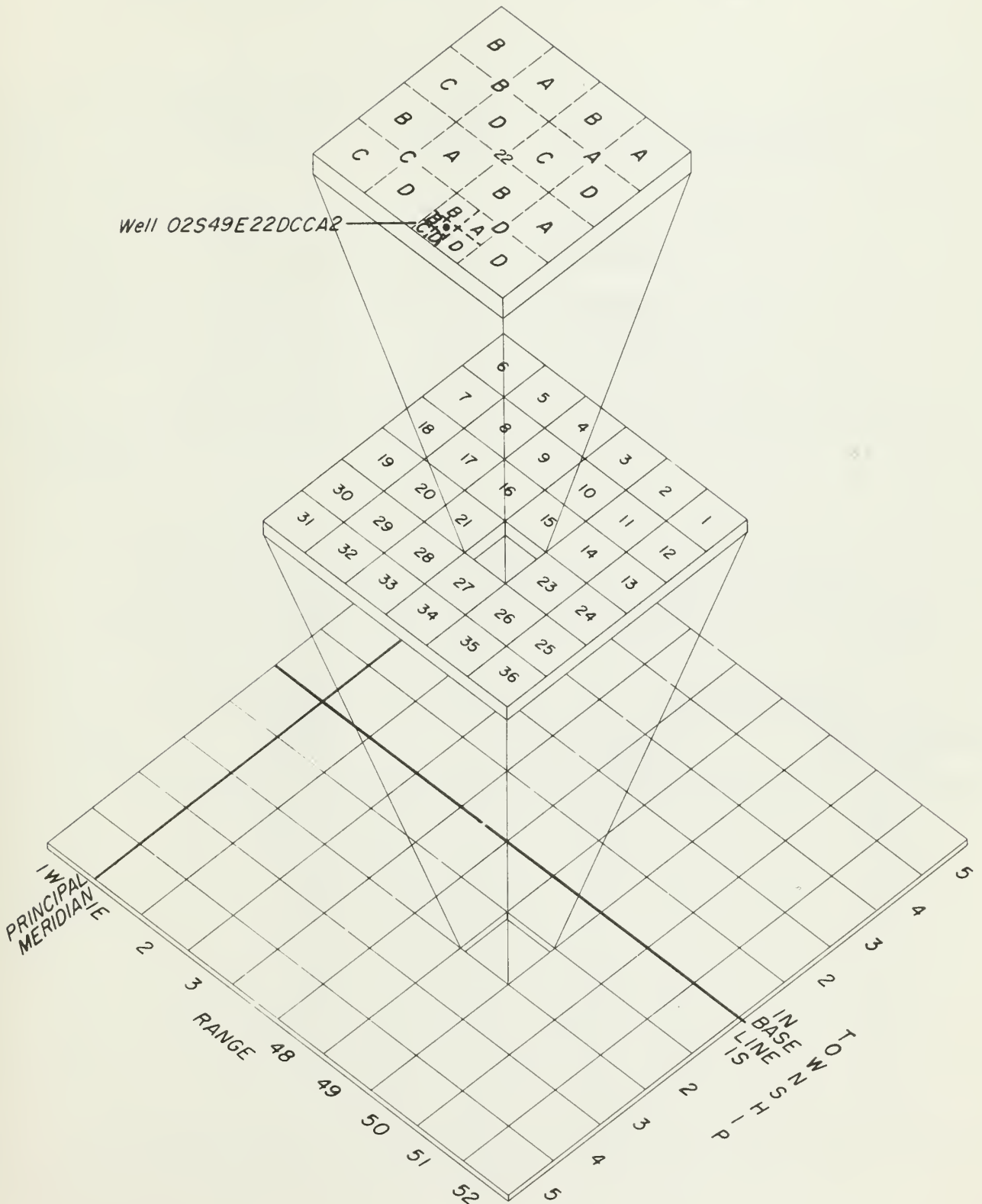


Figure 5 --System for describing geographic locations.



Table 67 -Annual peak discharge for Sixmile Creek  
tributary near Epsie

Date	Gage height (feet)	Discharge (ft <sup>3</sup> /s)	Method of determination
June 18, 1973	3.18	74	Indirect (Slope-area)
Apr. 20, 1974	3.13	70	Estimated
Mar. 03, 1975	<sup>1</sup> 2.50	5	Estimated
Jan. 18, 1976	2.05	2	Estimated

<sup>1</sup>Backwater

Table 68 -Estimates of flood discharge for selected subbasins  
[Estimates are based on an average annual precipitation of 14 inches.]

Subbasin	Drainage area (mi <sup>2</sup> )	Flood discharge	
		2-yr. frequency (ft <sup>3</sup> /s)	25-yr. frequency (ft <sup>3</sup> /s)
A	0.83	13	139
B	.43	7	82
C	.39	7	81
D	.88	13	145
E	1.07	16	163
F	.39	8	103



the stations were installed. Streamflow during early summer and winter is probably base flow from ground water discharge. All the water-quality sites have been dry by late summer when evapotranspiration was most effective.

According to monthly field inspections, the Pumpkin Creek station near Sonnette, upstream from the study area, recorded no flow from installation in October 1975 to October 1978 when it was discontinued. Similar streamflow conditions can be expected on Mizpah Creek upstream from the study site.

### Surface Water Quality

Single water samples were withdrawn from selected reservoirs after spring runoff in 1977. The samples were dipped near the shoreline at a depth of about 1 foot. Because the water surface of the reservoirs was disrupted by wind on the day of sampling, some mixing of the stored water was possible. However, the close correlation of air and water temperatures of the samples indicates that some thermal stratification probably existed. Therefore, the samples were collected from the upper more oxygenated layer of the water bodies and represent approximate quality of the reservoir water and surface-water runoff of upland drainages in the study area.

The samples collected from the reservoirs (Plate 46) were analyzed for common constituents and some nutrients (Table 70, Appendix F). All water samples were generally low in dissolved solids and nutrient concentrations and high in pH. The major cations from each reservoir were sodium, calcium, and magnesium; the major anions were sulfate, bicarbonate, and carbonate. Although dissolved-oxygen concentration was not determined, a significant concentration can be expected for all the reservoirs, because of inadequate mixing in the water bodies and the action of photosynthesis from abundant bottom vegetation.

Average annual sediment yield was estimated for subbasin F (Plate 46). From the age, sediment accumulation, and effective drainage area of the stock reservoir located at 03S49E22BCA, an average annual sediment yield of 0.06 ac-ft/mi<sup>2</sup> (acre-foot per square mile) was computed. This estimate could be lower than the actual average yield, because sediment carried over the spillway during periods of flooding is not accounted for in the computation.

Water samples collected from water quality stations on Pumpkin and Mizpah Creeks downstream from the study area have been analyzed for common ions and some for heavy metals (Table 69, Appendix F). Most of the water that flows at these stations is derived from ground-water discharge. Therefore, the water composition is characteristically distinct for each of the sampling sites. For example, predominant ionic constituents in water collected from Pumpkin Creek near Loesch (Figure 4) are sodium, magnesium, and sulfate. Those from Mizpah Creek at Olive are magnesium, sodium, calcium, and sulfate. The water type for base flow in both Pumpkin Creek near Volborg and Mizpah Creek near Volborg downstream from the study area (Figure 4) is sodium sulfate. Water at all stations has substantial amounts of nutrients and relatively low amounts of heavy metals. These levels are typical of slow moving and

ponded streamflow, which is used by livestock. The only constituent that is abnormally high for streamflow in this region is boron in water collected from Pumpkin Creek near Loesch (Table 69, Appendix F).

Although the character of water at each sampling site is generally consistent with time, some variation in dissolved solids concentrations results from local surface runoff and changes in evapotranspiration conditions. For example, dissolved solids concentrations are typically highest during the summer when evapotranspiration is most effective on the base flow. Conversely, concentrations are lowest during runoff periods when base flow is diluted. (Table 69, Appendix F). An exception to this trend occurs when runoff dissolves salts that have precipitated along drainage banks during seasonally dry periods, thereby increasing the dissolved solids concentration. This situation is evident from water sampled at Pumpkin Creek near Volborg on December 10, 1975, and at Pumpkin Creek near Loesch on January 7, 1977 (Table 69, Appendix F).

### Ground Water

The Pumpkin Creek Study Area is underlain by several aquifers. The shallowest aquifer is the coal-bearing Tongue River Member of the Fort Union Formation. The 140-foot-thick Lebo Shale Member of the Fort Union Formation underlies and separates the Tongue River Member from deeper aquifers, which include in descending order the Tullock Member of the Fort Union Formation, the Fox Hills-Lower Hell Creek aquifer, and the Madison Group. Owing to the low permeability of the Lebo Shale, the underlying aquifers are likely to be little affected by surface mining in the Tongue River Member of the study area.

The water table in the study area occurs within the Tongue River Member. This bedrock unit, which is composed mainly of shale, siltstone, fine-grained sandstone, and coal, is areally continuous throughout and beyond the limits of the study area. Because the water table generally conforms to the regional topography and the water-bearing strata are only gently dipping, the unconfined aquifer unit may be siltstone, sandstone, or coal.

In the study area, the water table lies within or below the Sawyer-"A" Coalbed. However, the drilling and testing of well 02S49E22DCCAL indicated confined conditions below a thin shale parting within the Sawyer-"A" Coalbed. Five of eleven test holes drilled through the Sawyer-"A" Coalbed had water within the coal. The water characteristically occurred in structural valleys or depressions of the gently undulating coalbed (Plate 19, Appendix C). The rest of the test holes were either dry to total depth drilled or had water levels in a sandstone below the Sawyer-"A" Coalbed.

Recharge to the unconfined aquifer in the study area is limited by evapotranspiration and vertical permeability of the unsaturated zone. Most potential recharge in the form of soil moisture is lost to evapotranspiration. Water that percolates below this zone is generally perched above a claystone or shale of low permeability before reaching the unconfined aquifer. This condition was evident from inspection of drill cuttings returned by air circulation while test drilling. The cuttings indicated alternating zones of moist and dry strata. Liquid

permeability tests were performed on selected cores to determine approximate confinement ability of certain lithologies to vertical water movement. The tests were run with water similar in quality and kinematic viscosity to typical ground water at the study area to facilitate conversion of coefficient of permeability to hydraulic conductivity. Vertical hydraulic conductivity for a silty shale sample from test hole 02S49E24BBCD was  $9.8 \times 10^{-6}$  ft/day (feet per day) and for a claystone sample from test hole 03S49E14CDBA was  $4.1 \times 10^{-7}$  ft/day. The presence of upland contact springs and seeps evident from field observations and colored infrared aerial photographs further demonstrate locally perched ground water.

The most significant areas to recharge to the unconfined aquifer within the study area are believed to be along certain outcrops of clinker. Units of clinker are sandstone, siltstone, and shale that have been baked and fractured by the burning of coalbeds. These highly permeable units occur almost entirely along the former outcrop of the Sawyer-"A" Coalbed and locally along certain outcrops of the Mackin-Walker Coalbed in the study area (Plate 17, follows page 18). Ground water is generally found closer to land surface near these outcrops, especially in the northern part of the site where the Sawyer-"A" clinker is most extensive. Examination of infrared aerial photographs shows more intense vegetation growth in tributary bottoms of this area, which may result from greater availability of water.

With respect to regional ground water movement in the Powder River structural basin, the East Pumpkin Creek Coalfield lies within a recharge area. A small part of recharge at the site moves downward from the aquifer units exposed at the surface to deeper aquifer units in the Tongue River Member. However, most of the ground water moves laterally northwest and northeast from the study area toward Pumpkin and Mizpah Creeks. Discharge to these valleys appears as base flow in the creeks or is evapotranspired where the depth to water is shallow.

Because of topography, geologic structure, and permeability differences of the water-bearing strata in the study area, local ground water movement may differ from the regional flow system. Although the Tongue River Member may be thought of as a water-table aquifer in a regional sense, it contains many thin confined or semiconfined water-bearing strata such as siltstone, fine-grained sandstone, or coalbeds that locally behave as separate aquifer units. Plate 47 shows the potentiometric surface of the shallowest aquifer units in the study area. The direction of ground water movement is generally perpendicular and downgradient to the potentiometric contours. Similarly, the contour spacing generally reflects the flow gradient. Except for a few instances, the ground water flow approximately follows the topography. In the northeast part of the study area, the trend of the gradient is approximately southwest as a result of structural dip of the aquifer units in that area (Plate 19, Appendix C). Also, local unconfined water movement, such as is possible in the Sawyer-"A" Coalbed, is apparently influenced by irregular structural configurations of the aquifer base.

A drawdown and recovery test was performed on test well 02S49E22DCCA1 to determine some hydraulic properties of the Sawyer-"A" Coalbed. The test well was pumped at a flow rate of 0.6 gal/min (gallons per minute)

for 8 hours. Water level changes were observed in four observation wells tapping the same unit and located equidistant in a semicircular pattern around the pumped well. The maximum and minimum drawdown directions for the test were N. 73°E. and N. 27°E., respectively. In the absence of irregular aquifer geometry or limiting boundary conditions, the drawdown differences suggest anisotropy related to fractures in the coal. The test indicated a transmissivity of 20 ft<sup>2</sup>/day (feet squared per day) and a storage coefficient of  $4.0 \times 10^{-4}$ . The hydraulic conductivity was 1.3 ft/day.

Another test was made on well 03S49E07DBDA, which taps a fine-grained sandstone aquifer unit below the Sawyer-"A" Coalbed. The well was pumped at 0.6 gal/min during the single-point test. A transmissivity of 400 ft<sup>2</sup>/day and hydraulic conductivity of 10 ft/day were determined from the data.

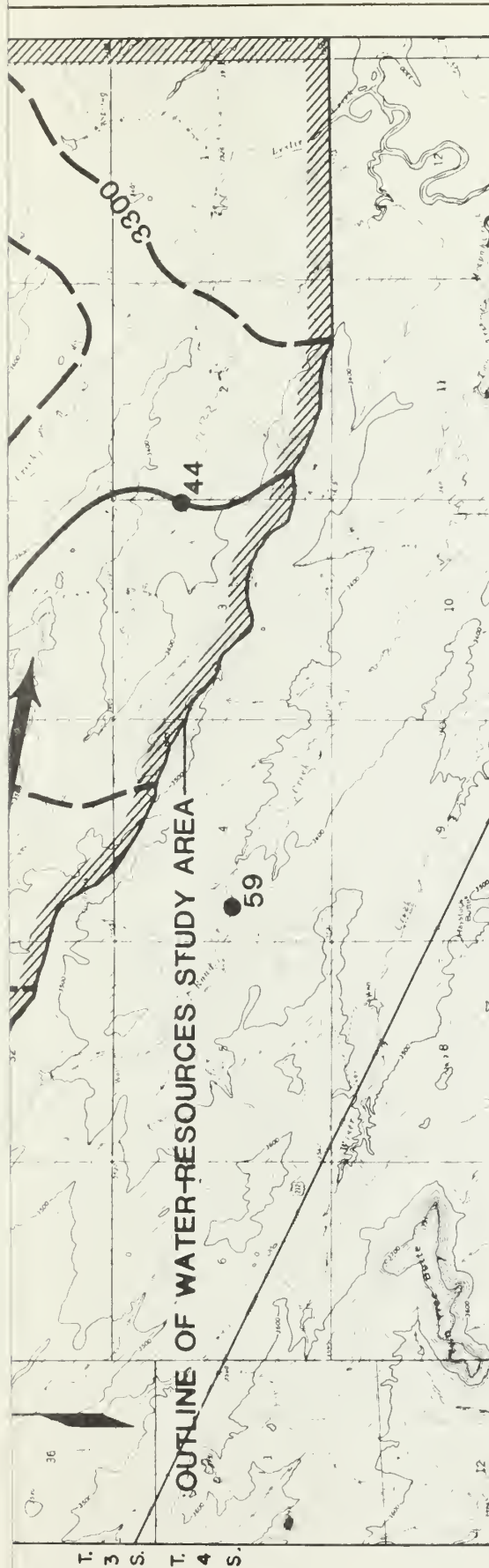
The preceding data analyses assumed that the coalbeds can be treated as single, confined, and anisotropic but homogeneous aquifers, and the sandstones can be treated as unconfined isotropic and homogeneous aquifers. Because of shallow penetration into the water table and low permeability, the remaining test wells were not tested for hydraulic parameters. These wells each produced less than 1 gal/min after being developed.

#### Ground Water Quality

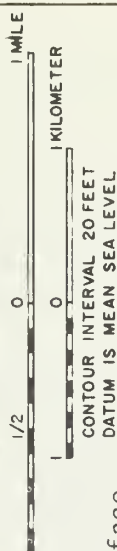
Chemical and radiochemical analyses of water from the Tongue River Member in the vicinity of the study area are presented in Table 71, Appendix F. The water samples were obtained from two developed springs and several stock wells and test wells which tap single or multiple aquifer units of sandstone, coal, or clinker. Sampling depths range from 7 to 150 feet.

The dissolved solids concentrations for samples of shallow ground water range from 397 to 4,340 mg/l (milligrams per liter). Sodium, calcium, and magnesium are the most abundant cations. Calcium and magnesium are generally similar in percentage of cations and generally less abundant than sodium. Sulfate and bicarbonate are the most abundant anions, but most analyses show sulfate as the predominant ion.

The variability of ground water quality in the study area is attributed to differing chemical environments that exist in the shallow ground water system. The abundance and composition of soluble minerals in aquifers and percolation zones, the flow path taken by the water, and the amount of time water resides in the ground are important conditions that affect ground water chemistry. These conditions also complicate the interpretation of specific geochemical processes that might be present. For example, no apparent consistency of water constituents in similar aquifer units has been noticed. Analyses of water from three wells (3, 5, and 14, in Table 71, Appendix F), tapping the same massive fine-grained sandstone aquifer unit, plot at three different locations of the water-analysis diagram of major ions (Figure 6). The same is true for analyses 2, 6, and 16 of water from the Sawyer-"A" or "A" Coalbeds (Figure 6). These inconsistencies probably result from differences in local circulation rates and recharge paths to the aquifer units.



# EXPLANATION



POTENTIAL SATURATION OF SAWYER-"A" COAL BED--Shows general area where base of Sawyer-"A" coal bed is below potentiometric surface

--- 3020 --- POTENTIOMETRIC CONTOUR--Shows altitude of uppermost continuous ground-water surface, 1975-77. Dashed where approximately located. Contour interval 20 feet. Datum is mean sea level

● 92 STOCK WELL--Number is depth to water in feet below land surface, 1975-77. Well taps aquifer units within Tongue River Member below Sawyer-"A" coal bed

○ 97 USGS TEST WELL--Number is depth to water, in feet below land surface, 1977. Well obtains water from Sawyer-"A" coal bed or underlying sandstone

⊘ 159 USGS DRY TEST HOLE--Number is total depth of hole, in feet below land surface

3510 SPRING OR SEEP--Number is altitude of land surface. Datum is mean sea level

➔ Direction of shallow ground-water movement in the Tongue River Member of the Fort Union Formation

PUMPKIN CREEK STUDY AREA  
EAST PUMPKIN CREEK  
COAL FIELD

Hydrogeologic Map--  
Potentiometric surface of  
shallow ground water

for 8 hours. Water level changes were observed in four observation wells tapping the same unit and located equidistant in a semicircular pattern around the pumped well. The maximum and minimum drawdown directions for the test were N. 73°E. and N. 27°E., respectively. In the absence of irregular aquifer geometry or limiting boundary conditions, the drawdown differences suggest anisotropy related to fractures in the coal. The test indicated a transmissivity of 20 ft<sup>2</sup>/day (feet squared per day) and a storage coefficient of  $4.0 \times 10^{-4}$ . The hydraulic conductivity was 1.3 ft/day.

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#### Ground Water Quality

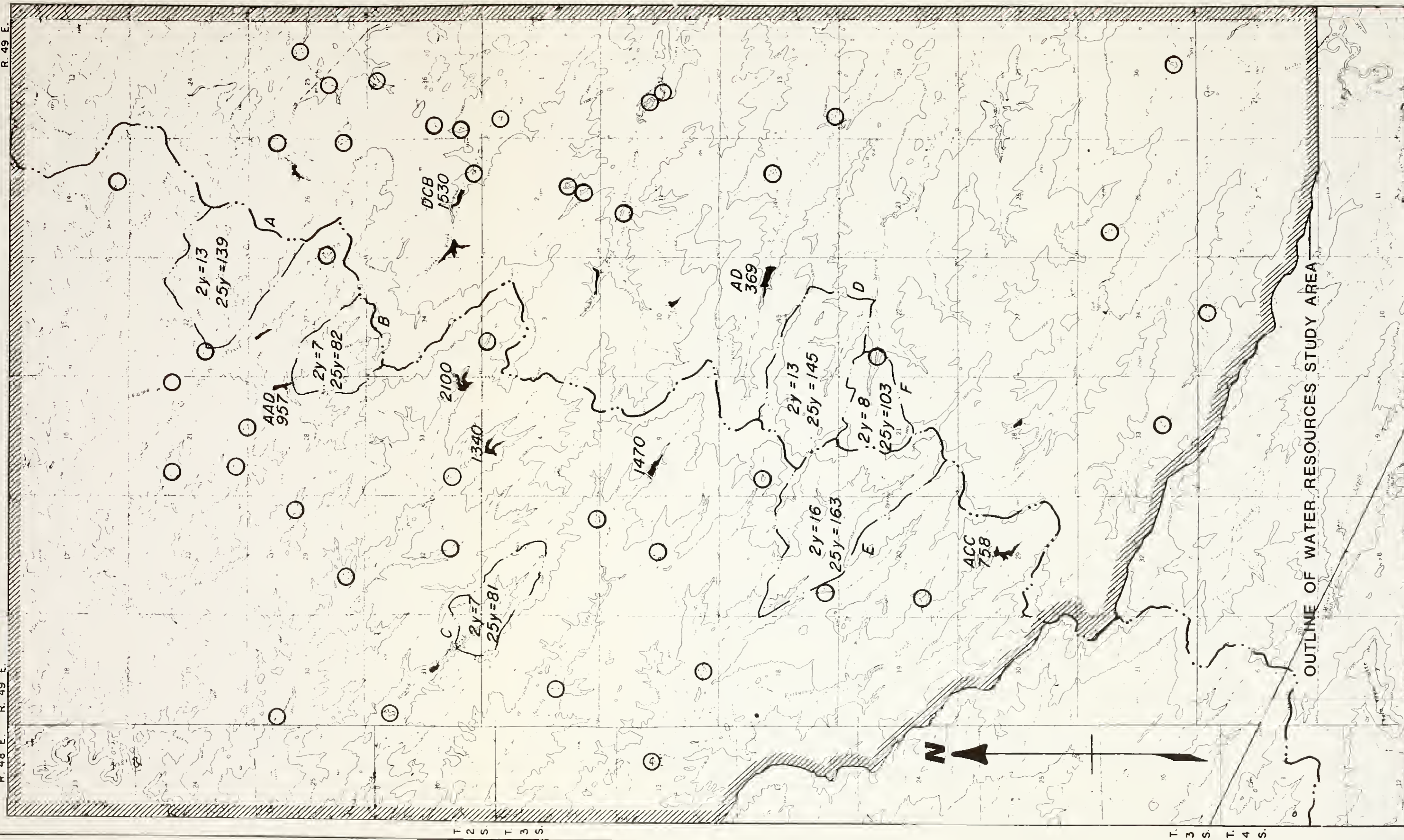
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R. 48 E. R. 49 E.

R. 49 E.



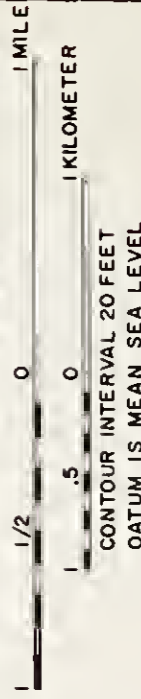
EXPLANATION

--- Drainage divide between Pumpkin and Mizpah Creeks

F: 2y=8, 25y=103  
Subbasin used in flood-frequency estimates. Numbers are 2-year and 25-year flood estimates, in cubic feet per second. Letter is identification in table 2

○ Ephemeral stock reservoir

AD 369  
Perennial stock reservoir. Letters denote tract location in table 4; number is specific conductance of dip sample



PUMPKIN CREEK STUDY AREA--  
EAST PUMPKIN CREEK  
COAL FIELD

Surface-water storage  
and runoff-distribution map



## EXPLANATION

- <sup>8</sup> Water analysis from Tongue River Member. Number is identification from table 71.



Figure 6 -Water-analysis diagram of water in the Tongue River Member.



Although specific trends in the geochemistry are not apparent from the available data, some general observations can be made. For instance, good quality water having relatively low dissolved solids concentrations for the area (analyses 8, 12, 14 and 16) can occur at shallow depths near potential local recharge areas. However, aquifers having these conditions are limited in extent and are not found throughout the study area. Another general geochemical trend apparent from water analyses 2, 6, 11 and 12 (Table 71, Appendix F) is that sodium and bicarbonate are more dominant in water suspected of having a long residence time in the aquifer unit.

The only other predominant ions were boron and strontium found in analysis 5. Although the concentrations were higher than in other samples, they were not unusual for water from the Tongue River Member.

### Water Use and Supply

Surface water and ground water in the Pumpkin Creek Study Area are low in quantity and fair in quality, but historically have been used for domestic, stock, and minor irrigation use. Stock reservoirs in the upland drainages are, in many instances, the only water supply available to livestock. The perennial reservoirs range in capacity from about 5 to 50 acre-feet, with an average of 20 acre-feet. Many ephemeral reservoirs supply adequate water for stock use through late spring during years of normal precipitation (Plate 46). Some of the spring runoff is collected by spreader dikes located along tributary drainages downstream from the reservoirs to irrigate hayfields.

The remainder of the water supply used for domestic and livestock purposes comes from wells and springs. Most of the wells produce water at a rate less than 12 gal/min from aquifer units of siltstone, sandstone, and coal in the Tongue River Member of the Fort Union Formation below the Sawyer-"A" Coalbed. However two large diameter wells, 03S49E02CACA and 03S49E16AADD, obtain water near the land surface from perched water conditions in a thin coalbed and a sandstone layer above the Sawyer-"A" Coalbed. Well 03S49E11BADC, which is the only well in the study area currently producing water from the Sawyer-"A" Coalbed, yields less than 2 gal/min. Springs 03S49E21BCCB and 03S49E34ABCC have been developed for livestock use. Both springs issue from coal beds at less than 4 gal/min.

Water sampled from the stock reservoirs had the lowest dissolved solids concentration and best overall quality. However, dissolved solids concentration in all water samples collected from the study area is below suggested upper limits for drinking by cattle (McKee and Wolf, 1963).

### Mining Effects on Hydrology

The effects of surface mining on the area hydrology depend on the depth to which coalbeds will be stripped and the areal extent of mine development. The following discussion assumes that the Sawyer-"A" Coalbed would be the deepest mined coalbed in the study area.

Ground water problems associated with surface mining within the study area are expected to be minimal. In about half of the East Pumpkin Creek Coalfield, a mine floor (base of Sawyer-"A" Coalbed) would be above saturated rock. Thus, dewatering would not be necessary. Plate 47 is shaded in areas where the potentiometric surface is higher than the base of the Sawyer-"A" Coalbed. This local saturation essentially follows the ground water divide and two linear depressions in the coalbed structure. The greatest potential submergence of the base of the Sawyer-"A" Coalbed is 60 feet in the area of 03S49E09A.

Where the coalbed is saturated, it is likely to be slowly permeable and dewatering should be slow and controllable. Given the condition of a mine strip having a shape approximated by a  $\frac{1}{2}$ -mile radius semicircle at a depth of 10 feet below static water level, mine inflow is estimated by a form of Darcy's law to be less than 10 gal/min ( $0.08 \text{ ft}^3/\text{s}$ ). This estimate assumes an imposed hydraulic gradient of  $0.1 \text{ ft/ft}$  and a transmissivity of  $4 \text{ ft}^2/\text{day}$ .

The effects of mining on existing water wells are expected to be slight. Only one well in the study area taps the Sawyer-"A" Coalbed. However, six wells which tap deeper aquifer units could be removed by mining. Three springs within the study area also could be consumed by surface mining.

The greatest potential adverse effect on the shallow ground water system from surface mining in the study area would be water quality degradation. Mining strips are possible localities of ground water recharge wherever the head gradient is downward. Water polluted by mining operations such as by explosives, fuel and oil spill, or contaminated runoff from toxic overburden spoils could percolate below the mine floor into deeper aquifers. This consideration is more important in the northern and eastern flanks of the study area where water-bearing units of the Fort Union Formation generally dip away from potential coal mining strips.

Spoils from surface mining could cause changes in ground water quality. The character of these changes is difficult to predict without mineralogical data of the implaced spoils. Recharge to existing shallow aquifer units during postmining conditions is expected to be small through implaced spoils, and more significant near aquifer outcrops to the north and west of strippable coal areas.

In general, unchecked hydrologic changes during surface mining could reduce surface runoff and increase sediment loads to ephemeral drainages directly below mine cuts. Little change in streamflow and water quality of Pumpkin and Mizpah Creeks should result from surface mining in the study area. Most of the annual flow of these streams is a result of regional ground water discharge. The effects of mining during periods of high runoff are also expected to be low because the effective drainage area through the study area is proportionally small compared to the drainage basin area of each stream. In addition, stock reservoirs, catchments, and irrigation diversions presently located between these streams and potential surface mining strips would attenuate most runoff changes caused by surface mining.

Surface mine strips along the Pumpkin Creek Study Area could potentially remove 12 perennial and 25 ephemeral stock reservoirs. Reservoirs replaced after mining would be affected by the infiltration capacity of reclaimed spoils, rate of runoff from disturbed areas, and quality of the runoff.

## CONCLUSIONS

### CLIMATE

Climate may be a limiting factor for revegetation in the Pumpkin Creek Study Area. Generally, the continental-type semiarid climate has a sufficiently long frost-free period and adequate precipitation, especially during the early part of the growing season, to support the growth of native range plants on suitable plant growth material.

The average annual rainfall in this study area is about 13.8 inches. Of this amount, approximately 73 percent occurs during the growing season (April through September). The average annual temperature for the area is about 45.1 degrees F, with temperature extremes of 108 degrees F in summer and -42 degrees F in winter being quite probable. The frost-free period (> 32 degrees F) is estimated at 100 to 128 days, and the growing season for hardy crops (> 28 degrees F) is approximately 144 days.

Climatic factors that may adversely affect revegetation efforts in this study area include: (1) below normal or uneven distribution of precipitation, especially during the growing season, (2) severe thunderstorms and/or strong winds that cause erosion, (3) late spring freezes, and (4) depletion of soil moisture by wind.

More detailed investigations will be necessary prior to mining to more accurately determine probabilities of occurrence of these factors. This data can then be used to predict best possible seeding times for revegetation.

### PHYSIOGRAPHY

The Pumpkin Creek Study Area is located in the northern part of the Powder River Basin in Powder River County, Montana. This basin lies within the unglaciated Missouri Plateau section of the Great Plains Physiographic Province. Pumpkin Creek, a tributary to the Tongue River, forms the western border of the study area.

The surface relief in the study area is about 350 feet, with elevations ranging from 3350 feet to 3700 feet.

Drainage of the study area is accomplished through an extensive system of branching natural drains (dendritic pattern). The general flow of drainage is northward toward the Yellowstone River via Pumpkin Creek and the Tongue River.

### COAL RESOURCES

The Pumpkin Creek EMRIA Site, an area of about 94 square miles, is located mainly in the southwestern part of the Coalwood Coalfield on the slightly westward dipping beds of the Tongue River Member of the Paleocene Fort Union Formation.

Three coalbeds: A, Sawyer, and Mackin-Walker, were evaluated by 32 drill holes. Coal resources - measured, indicated, and inferred - within the site and in beds more than 5 feet thick under less than 1000 feet of overburden are 191,660,000 short tons, 1,356,950,000 short tons, and 34,400,000 short tons, respectively.

The coal has an apparent rank of lignite A as shown by the analyses of 17 core samples. The average Btu value of 15 core samples of the Sawyer from the site on the as-received basis is 6,970; average ash content is 6.8 percent; and average sulfur content is 0.4 percent. The Mackin-Walker has a Btu value of 7,220, an ash content of 6.9 percent, and a sulfur content of 1.0 percent.

A comparison of the analyses of samples from the Sawyer coalbed with other analyses of Powder River region coal samples shows that moisture, hydrogen, and oxygen contents are significantly higher, and volatile matter, fixed carbon, carbon, nitrogen, and total sulfur contents and heat of combustion are significantly lower in the Sawyer bed samples. A statistical comparison of the elemental compositions of the two sample groups shows that the Sawyer bed has significantly higher contents of B, Ba, Mn, Nb, U, Y, and Yb and significantly lower contents of Be, Co, Cr, Cu, Ni, Pb, Sc, Se, and Th.

The sample of the lower split of the Sawyer bed (bed A) in drill hole PW8 has a relatively high sulfur content of 1.7 percent, and presumably would not be mined with the rest of the Sawyer.

## GEOLOGY

The Pumpkin Creek Study Area is in the northern part of the Powder River Basin. This deep sedimentary basin is about 225 miles long and 90 miles wide. It extends from the Yellowstone River in Montana to the North Platte River in Wyoming and from the Black Hills of South Dakota to the Bighorn Mountains of Wyoming.

Bedrock exposed in the study area is the Tongue River Member of the Fort Union Formation of Paleocene Age. Unconsolidated alluvial and terrace deposits of Holocene and Pleistocene Age mantle the valley floors and benches along the major drainages.

Engineering property tests performed on bedrock materials similar to those in the Pumpkin Creek Study Area revealed that shear strengths are low. Slides can develop adjacent to high walls in surface mines, and saturated alluvial deposits and uncemented siltstones and fine-grained sandstone will readily erode and flow into excavations.

Excavation slopes will vary between minesites and will be dependent on exposure time, moisture conditions, material types, and depth of cut.

After disturbance, an increase of about 25 percent will occur in the volume of the overburden. Some areas of the surface will actually be higher in elevation after mining. Settlement will then occur for several years after reclamation until the materials reach a stable condition.

Three types of instability are common on reclaimed coal-mined areas in the Northern Great Plains. They are: (1) areawide settling, (2) localized collapse, and (3) piping. Each form of instability is affected by certain variables in the postmining landscape. These variables include the physical and chemical characteristics of the overburden, the method and equipment used in stripping and contouring operations, and the season when these activities occur. One or more of these types of landscape instabilities may occur on reclaimed land in the Pumpkin Creek Study Area.

Weathering tests conducted on bedrock core samples from the study area showed that shale samples break down more readily than either siltstones or sandstones, but handling these clay-rich materials may be difficult because of their plasticity.

A study of the seismic history of the region indicates that minor damage could result to structures from earthquake shocks.

#### OVERBURDEN - SOIL AND BEDROCK

Soils of the Pumpkin Creek Study Area can be grouped into three major categories based on their parent material and landform position. These are: (1) residual soils developing over weathered shale or sandstone which occupy ridges, buttes, and gentle to steep sideslopes, (2) transported (alluvial/colluvial) soils forming over mixed deposits of soil material and rock fragments which occur on fans, footslopes, and in swales, and (3) alluvial valley floor soils developing over deep water-lain deposits on nearly level bottomlands adjacent to major tributary drainages. The residual soils occur over approximately 78 percent of the study area; the transported soils occupy about 17 percent of the study area; and the alluvial valley floor soils comprise the remaining 5 percent.

A semidetalled land suitability survey of the Pumpkin Creek Study Area was made to evaluate and characterize the overburden (soil/bedrock to a depth of 10 feet) as a source of material for resurfacing and revegetating the area if it is surface-mined. This survey provides data on the quantity, quality, and ease of stripping and stockpiling the usable material. Basic data on the physical and chemical properties of the soils and bedrock are also provided by this survey.

Four land classes: 1, 2, 3, and 6 were established to group land of equal suitability for the specific use of revegetation. Class 1 lands provide the most desirable and plentiful source of easily stripped revegetative material. Land in this class generally has surplus suitable material that can be utilized in deficient areas. Class 2 lands contain an adequate supply of resurfacing material to revegetate the immediate area; however, this material is slightly less desirable in quality or somewhat more difficult to strip and stockpile than the material in Class 1 lands. Class 3 lands are similar to those in Class 2, except the deficiencies are more pronounced or a combination of deficiencies exists. Though they are marginally suitable, Class 3 lands can generally meet the plant media requirements for revegetation. Class 6 lands lack adequate quantities of suitable material to meet the needs for revegetation. If these lands are disturbed by surface mining, it will be necessary to borrow the material from Class 1 or 2 lands or modify the material available for revegetation through leaching, chemical amendments, etc.

The results of the land suitability survey of the Pumpkin Creek Study Area expressed as a percentage of the area are as follows: Class 1 - 14.1, Class 2 - 24.4, Class 3 - 26.0, and Class 6 - 35.5.

Based on the field and laboratory data obtained from the land suitability survey, it appears that most of the residual, transported (alluvial/colluvial), and alluvial valley floor soils in this study area should yield about 6 to 12 inches of fair to good quality topsoiling material. This material, which generally includes the A and B horizons, is typically nonsaline, nonsodic, and moderately permeable.

Many of the soil profiles showed a moderate to strong increase in soluble salts, exchangeable sodium, and/or clay content between 12 and 18 inches in depth (C horizons). Therefore, a significant percentage of the available subsurface materials in this study area were classified as fair or poor for placement below the primary plant rooting zone in reconstructed profiles.

A systematic evaluation was made of the geologic core samples from Bureau of Reclamation Drill Holes 76-101 and 77-102 through 110 in order to determine suitability of the bedrock materials for use as plant media.

A complete set of laboratory data, including trace elements, provided the data base necessary to evaluate the bedrock materials. Although similar criteria were used for both the land suitability survey and bedrock suitability evaluation, different suitability classes were assigned to the bedrock materials. These classes are "suitable," "limited suitability," and "unsuitable." The suitable class corresponds to Class 1 and the higher quality Class 2 materials; the limited suitability class includes the lower quality Class 2 and Class 3 materials; and the unsuitable class is equivalent to Class 6.

Overall, only 3 percent of the bedrock materials overlying the Sawyer/A coalbed in this study area were determined to be suitable for use as plant media, 14 percent were of limited suitability, and 83 percent were classified as unsuitable.

Excessive exchangeable sodium was the major limiting factor for the unsuitable materials. In 8 of the 10 drill holes, the highly sodic materials were overlain by 10 to 35 feet of nontoxic soil and bedrock. However, the remaining two drill holes were sodic to the surface. Placement of these materials at or near the surface in reconstructed profiles could seriously impair plant reestablishment. Therefore, these materials should be selectively placed well below the plant rooting zone. Other factors causing materials to be classified as unsuitable included high salinity, high clay percentage, and slow permeability.

The bedrock materials placed in either the suitable or limited suitability class could be utilized as subsurface material (below the primary plant rooting zone) on lands lacking an adequate supply of suitable material. However, separating and stockpiling these materials may be difficult.

Based on the physical and chemical limitations of the soils and bedrock materials described in this report, reconstruction of a profile suitable for successful plant reestablishment would be more difficult in the Pumpkin Creek Study Area than in other study areas previously investigated in southeastern Montana under the EMRIA program.

## GREENHOUSE EVALUATION OF OVERBURDEN MATERIALS

Western wheatgrass was chosen as the primary test species for this study since it is one of the most abundant native plant species in the western United States and will probably be used in many revegetation operations.

Based on the results of soil and plant analyses and calculation of relative yields, the soil and bedrock samples were assigned ratings of suitable, questionable, or unsuitable for use as revegetative media.

The soil samples were rated 38 percent suitable, 34 percent questionable, and 28 percent unsuitable. The bedrock samples were rated 12 percent suitable, 20 percent questionable, and 68 percent unsuitable.

Salinity and/or sodicity problems appeared to be the major limiting factors for most of the materials classified as unsuitable. However, other factors which may have had a role in producing low relative yields included low levels of available phosphorus and low field capacities.

The greenhouse serves as an excellent tool for stratifying overburden materials as to their relative productivity. However, it must be noted that the percentage results listed above were obtained under controlled conditions. These results should not be used to predict revegetation potential under actual field conditions.

## HYDROLOGY

### Surface Water

Streamflow in the Pumpkin Creek Study Area occurs in response to spring and rainstorm runoff. Flow estimated for an ephemeral drainage area of 1 mi<sup>2</sup> with 25-year frequency may be as high as 160 ft<sup>3</sup>/s. Most of the runoff is intercepted by small reservoirs and hayfield irrigation before reaching Pumpkin and Mizpah Creeks.

Surface water quality is variable and depends on local conditions of surface runoff, evapotranspiration, and ground water. Water from selected perennial reservoirs is low in dissolved solids and nutrients, but high in pH. Average annual sediment yield to a selected stock reservoir was estimated to be about 0.06 acre-foot/mi<sup>2</sup>. Water flow downstream from the study area is generally high in dissolved solids during base flow. Dilution of base flow is noticeable during periods of surface runoff.

### Ground Water

Shallow water occurs in permeable units of the Tongue River Member of the Fort Union Formation. The potentiometric surface of the shallowest ground water generally conforms to area topography within or below the lowest strippable coal. Local perching of water is apparent above confining layers. Movement of water is controlled by topography, structure, and local recharge. Hydraulic conductivities determined from aquifer tests in coal and sandstone were less than 10 ft/d.

Ground water quality is also variable and may be attributed to circulation of recharge and heterogeneous minerology along flow paths in the Tongue River Member. Dissolved solids concentration is low to moderate. The most abundant cations are sodium, calcium, and magnesium. The most common anions are sulfate and bicarbonate.

#### Effect of Mining on Water Resources

Ground water problems associated with surface mining of the Sawyer "A" Coalbed are expected to be minimal. Mining of strippable coalbeds would partially drain saturated coal at a slow rate in the study area. One well could be dewatered and six wells and three springs could be removed by strip mining. The water quality in aquifer units below the mined coalbed will be unaffected if proper precautions are taken during closing of existing deep wells.

Surface mining would not significantly affect streamflow outside the study area. However, mining could remove 12 perennial and 25 ephemeral reservoirs. Dissolved solids and sediment concentrations could increase in reservoirs downstream from mine strips.

#### VISUAL RESOURCE CONSIDERATIONS

According to Bureau of Land Management planning documents, the Pumpkin Creek Study Area has average scenic values with low visual exposure. The visual resource is not an important factor; therefore, it will not require special consideration in reclamation planning.

## RECOMMENDATIONS FOR RECLAMATION

### INTRODUCTION

If surface mining occurs in the Pumpkin Creek Study Area, the mine operator will be required to restore all disturbed areas "in a timely manner, either to conditions capable of supporting the uses they were capable of supporting before any mining or to conditions capable of supporting approved alternative land uses" /Rule XVI(5)(c) pursuant to the Montana Strip and Underground Mine Reclamation Act - Montana Permanent Program/.

Unless an alternative postmining land use is desired by the landowner(s) and approved by the Montana Department of State Lands, the main objective of reclamation in the Pumpkin Creek Study Area will be to establish a diverse vegetative cover with an interspersation of vegetative types over the reclaimed land capable of supporting livestock and wildlife. The integrity of the visual resource should be maintained.

### STABILITY OF THE POSTMINING LANDSCAPE<sup>1/</sup>

The design of a stable postmining landscape in the Pumpkin Creek Study Area will require the integration of several critical factors. These include: (1) a detailed knowledge of the distribution of overburden materials, with emphasis on the delineation of highly sodic spoils, (2) proper equipment selection, and (3) a consideration of seasonal factors. For reclamation to be successful, consideration must be given to the entire landscape, not merely the soil zone.

Three forms of landscape instability are common on reclaimed coal-mined areas in the Northern Great Plains. These are areawide settling, local collapse, and piping.

Areawide settling is common in most postmining landscapes, but appears to cause only minimal disruption. This form of subsidence will probably be most pronounced during the first year following reclamation and will continue at a decreasing rate for a number of years. The two major factors influencing areawide settling are: (1) texture of the overburden, and (2) equipment used in spoil contouring operations.

A significant quantity of overburden in the Pumpkin Creek Study Area consists of fine-textured material (shale). When disturbed, this material usually results in more blocky and, initially, more porous spoils than does coarse-textured overburden (sandstone). Therefore, a greater degree of areawide settling may be expected in this area as compared to an area where coarse-textured materials are predominant.

Equipment used in contouring operations is a critical factor influencing areawide settling. Settlement is significantly less in scraper-contoured

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<sup>1/</sup> Groenewold, G.H. and Rehm, B.W., 1980 (modified).

areas than in dozer-contoured areas due to the fact that scrapers more effectively break down large overburden blocks and compact the spoil mass. Therefore, the degree of areawide settlement may be reduced by employing scrapers rather than dozers in spoil contouring operations.

Local large-scale collapse often develops soon after contouring is completed. Development typically ends within 1 year. This form of instability is predominant in precontouring valleys where large, frozen spoil blocks are concentrated by mid-winter dozer contouring. Thawing of these blocks results in local surface subsidence. To restrict the development of local collapse features, the use of scrapers rather than dozers should be considered for contouring operations during the winter months.

Piping appears to be a severe and long-term problem in some postmining landscapes. This form of instability usually begins soon after contouring ceases and may continue for several years. In some postmining landscapes, piping has only started to develop after as much as 5 years.

Piping is apparently controlled by a combination of physical and chemical conditions in the spoils. All piping begins as a crack, either on the surface of exposed spoils or at the topsoil-spoil interface. In the latter case, the overlying topsoil collapses into the pipe and is carried away. Repeated topsoil application is usually unsuccessful in stopping the growth and development of piping. Cracking of spoils is restricted to areas of highly dispersive sodic materials. The cracks allow access for large volumes of surface runoff to flow into the subsurface of the spoils. However, surface cracking alone will not necessarily result in the development of piping. Piping will develop only if an avenue for water movement can result from fracturing within the mass of spoils due to settling between differentially compacted areas (i.e., scraper-contoured area adjacent to dozer-contoured area) or within areas of poorly compacted spoils (i.e., dozer contouring only).

Piping usually develops in nearly flat areas, where runoff is minimal and infiltration is maximized. Thus, the final surface slopes in reclaimed areas must also be recognized as controlling factors in the development of piping.

Given the proper conditions of slope, near-surface dispersive materials, and a permeable zone in the base of the spoils, piping may continue to develop and disrupt the restored landscape for many years. Selective placement of excessively sodic overburden encountered in this study area may prove to be the only effective means of controlling piping.

Because the postmining landscape in the Pumpkin Creek Study Area will be unstable, structures should not be built unless they are specifically designed to absorb differential settlement. Also, reconstructed drainage channels will require periodic maintenance to ensure that ponded areas do not develop in areas of localized settling.

## GRADING AND HANDLING OF SPOIL MATERIALS

Montana law presently requires that "All final grading on the area affected shall be to the approximate original contour of the land" /Rule IV(1)(b) pursuant to the Montana Strip and Underground Mine Reclamation Act - Montana Permanent Program/. Furthermore, the mine operator will be required to "transport, backfill, compact (where advisable to ensure stability or to prevent leaching of toxic materials), and grade all spoil material to eliminate all highwalls, spoil piles, and depressions" /Rule IV(1)(d) pursuant to the Montana Strip and Underground Mine Reclamation Act - Montana Permanent Program/.

Where possible, all final grading and preparation of graded land prior to the redistribution of topsoil should be conducted along the contour to minimize erosion and maximize landscape stability.

Based on the results of laboratory analyses performed on samples from 10 drill holes in the Pumpkin Creek Study Area, it appears that a significant percentage of the bedrock strata contain excessive levels of sodium. Ideally, excessively sodic or other toxic materials should be covered with a minimum of 8 feet of nontoxic overburden. However, based on the data presented in this report, it appears as though the quantity of nontoxic overburden required to accomplish the 8-foot covering may be deficient in this study area.

## EROSION CONTROL

Reducing runoff and erosion and increasing the on-site conservation of moisture for vegetative establishment are feasible objectives for reclaimed land in the Pumpkin Creek Study Area. The following procedure is recommended as a means toward achieving these objectives: (1) reduce the mean surface slope in the reclaimed area, (2) scarify the surface of the regraded spoils, (3) replace the subsoil/topsoil and prepare a seedbed, (4) conduct seeding and planting operations as soon as possible after topsoil redistribution, and (5) apply mulch to the newly seeded areas.

Reducing the mean surface slope in the reclaimed area will provide a more gently sloping landscape. A more level landscape will increase the potential for infiltration and moisture retention and decrease the potential for runoff and sediment yield. The increase in moisture retention will be highly desirable for plant reestablishment in the reclaimed area.

Prior to the redistribution of suitable plant growth material, the surface of the regraded spoils should be ripped or chiseled in order to (1) eliminate slippage surfaces at the spoil-topsoil interface, and (2) provide a favorable subsurface medium for air/water infiltration and root penetration. Ripping or chiseling should be conducted along the contour wherever possible to prevent runoff and ensure maximum stability.

Subsoil and topsoil are often compacted by heavy machinery during the redistribution process. These materials should be loosened by chiseling or other means prior to actual seedbed preparation (disking/harrowing). The loosened material will allow roots to readily penetrate its matrix and

will also facilitate a higher rate of air/water infiltration. All tillage operations should be conducted along the contour to prevent excess runoff and substantial loss of the plant growth material.

Seeding and/or planting should be conducted as soon as possible after the topsoil has been spread and a seedbed has been prepared. The establishment of a permanent vegetative cover as quickly as possible will be the most effective method of controlling erosion in the reclaimed area. A temporary cover of small grains, grasses, or legumes may be required to protect the topsoil until such time as a permanent cover can be established.

Suitable mulch should be applied on all newly seeded areas to control erosion, conserve soil moisture, and enhance seed germination. The application of hay or straw mulch at a rate of about 2 tons/acre should be considered for the Pumpkin Creek Study Area. To prevent substantial losses of the mulching material due to blowing, the hay or straw should be anchored (disked or crimped) to the soil surface.

### REVEGETATION

Revegetation of surface-mined land in the Pumpkin Creek Study Area will require: (1) removal, segregation, and redistribution of suitable plant growth material, (2) selection of adapted plant species, and (3) use of proper seedbed preparation and planting procedures.

#### Removal, Segregation, and Redistribution of Suitable Plant Growth Material

Montana regulations require that "All available topsoil shall be removed from the area of land affected before further disturbance occurs. The operator shall segregate surface soil material (A and possibly portions of underlying B and C horizons) from subsurface material (B and C horizons) in the salvage, stockpiling, and redistribution of topsoil" (Rule VIII(1) pursuant to the Montana Strip and Underground Mine Reclamation Act - Montana Permanent Program). The segregation of surface soil material and subsurface soil material is accomplished in a 2-lift process, with the most desirable plant growth material (topsoil) being removed in the first lift and the remaining suitable material (subsoil) being salvaged in the second lift. Based on the results of the Land Suitability Survey included in this report, it appears that a minimum of 6 inches of fair to good quality surface material (topsoil) could be removed in the first lift from most soils in this study area (see Plates 33 through 36 following page 26). This material is typically nonsaline, nonsodic, and moderately permeable. The quantity and quality of subsurface material (subsoil) in this study area is highly variable (see Plates 37 through 40 following page 26).

Ideally, topsoil/subsoil redistribution should proceed concurrently with the mining operation. However, if stockpiling of the suitable plant growth material is necessary, the stockpiles should be selectively placed on a stable area and protected from erosion, compaction and contaminants (toxic spoils). Establishment of a quick growing vegetative cover on the stockpiles is probably the most effective method of protection; however, other measures such as snow fences, mulches, or chemical binders may also be considered.

Before the suitable plant growth material is redistributed, the regraded land should be scarified (ripped) to eliminate slippage surfaces and enhance root penetration. The redistribution of subsoil and topsoil, respectively, should proceed in a manner that achieves an approximate uniform thickness consistent with the postmining land use(s) and prevents excess compaction of the spoils and suitable plant growth material.

Finally, nutrients (fertilizer) and/or soil amendments should be added to the surface soil layer in the amounts determined by soil tests. All soil analyses should be performed by a qualified laboratory using procedures approved by the Montana Department of State Lands.

#### Selection of Adapted Plants

To comply with present State regulations, "A diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area of land to be affected . . . shall be established on all areas of land affected except water areas and the surface area of roads that are approved as a part of the postmining land use" [Rule IX(1) pursuant to the Montana Strip and Underground Mine Reclamation Act - Montana Permanent Program]. Introduced species may be approved for use by the Department of State Lands if appropriate field trials demonstrate that the introduced species are of equal or superior utility for the approved postmining land use or are necessary to achieve a quick, temporary, and stabilizing cover.

Some important considerations in selecting plant species for revegetation in the Pumpkin Creek Study Area should include: drought resistance, salt and sodium tolerance, resistance to winterkill, palatability, and resistance to grazing pressure. Of equal importance is plant compatibility with soil type, slope, aspect, and drainage conditions. Table 72 is an example listing of adapted plant species and seeding rates which could be considered for use in the Pumpkin Creek Study Area.

The establishment of a diverse vegetative cover with an interspersed of vegetative types over the reclaimed land will aid in restoring wildlife habitat in the area.

#### Seedbed Preparation and Planting

To provide a plant medium favorable for air and water infiltration, as well as root penetration, the topsoil/subsoil should be chiseled to a depth of 18 to 24 inches prior to seedbed preparation. Disking/harrowing should then be conducted until a suitable seedbed is achieved.

Seeding of grasses and legumes with a press drill is usually the preferred technique; however, broadcasting is also widely accepted. Drilling is considered superior because the seed is covered to a proper depth, rate of seeding is controlled, seed distribution is uniform, and soil compaction can be accomplished with packer wheels attached to the drill. Broadcasting is considered less efficient because the seeds often perch on top of the soil, where germination and establishment are difficult. Seed that is broadcast

RANGELAND SEED MIXTURE<sup>2/</sup>

		<u>Lbs./Acre</u>
Western Wheatgrass	<u>Agropyron smithii</u>	4.0
Thickspike Wheatgrass	<u>Agropyron dasystachyum</u>	2.0
Slender Wheatgrass	<u>Agropyron trachycaulum</u>	3.0
Whitmer Beardless Wheatgrass	<u>Agropyron inerme</u>	3.0
Pubescent Wheatgrass	<u>Agropyron trichophorum</u>	1.0
Alkali Sacaton	<u>Sporobolus airoides</u>	1.0
Green Needlegrass	<u>Stipa viridula</u>	3.0
Sainfoin	<u>Onobrychis viciaefolia</u>	3.0
Sideoats Grama	<u>Bouteloua curtipendula</u>	2.0
Indian Ricegrass	<u>Oryzopsis hymenoides</u>	1.0
Four-wing Saltbush	<u>Atriplex canescens</u>	1.0
*Purple Prairie Clover	<u>Petalostemon purpureum</u>	0.25
*Big Sagebrush	<u>Artemisia tridentata</u>	0.125
*Blue Flax	<u>Linum perenne</u>	0.25
*Western Yarrow	<u>Achillea millefolium</u>	0.25
	Total	<u>24.875</u> <sup>3/</sup>

\*All seed, except for these, are pure live seed.

DRAINAGE/LOWLAND SEED MIXTURE<sup>2/</sup>

		<u>Lbs./Acre</u>
Green Needlegrass	<u>Stipa viridula</u>	2.0
Western Wheatgrass	<u>Agropyron smithii</u>	4.0
Thickspike Wheatgrass	<u>Agropyron dasystachyum</u>	4.0
Pubescent Wheatgrass	<u>Agropyron trichophorum</u>	2.0
Regar Brome	<u>Bromus bierbersteinii</u>	1.0
Canada Wild Rye	<u>Elymus canadensis</u>	1.0
Cicer Milkvetch	<u>Astragalus cicer</u>	1.0
Eski Sanfoin	<u>Onobrychis viciaefolia</u>	3.0
*Western Yarrow	<u>Achillea millefolium</u>	0.25
*Silver Sagebrush	<u>Artemisia cana</u>	0.125
*Wild Rose	<u>Rosa spp.</u>	0.25
*Western Snowberry	<u>Symphoricarpus occidentalis</u>	0.25
	Total	<u>18.875</u> <sup>3/</sup>

\*All seed, except for these, are pure live seed.

<sup>2/</sup> From: Draft Environmental Statement - West Decker Mine, Bighorn County, Montana, Montana Department of State Lands, 1980.

<sup>3/</sup> Rates listed are for drill seeding. For broadcast seeding, rates should be doubled.

TREE/SHRUB INCLUSIONS FOR DRAINAGES/LOWLANDS

Ponderosa Pine	— <u>Pinus ponderosa</u>
Common Chokecherry	<u>Prunus virginiana</u>
Skunkbush Sumac	<u>Rhus trilobata</u>
Cottonwood	<u>Populus spp.</u>
Willow	<u>Salix spp.</u>
Russian Olive	<u>Elaeagnus angustifolia</u>
Siberian Peashrub	<u>Caragana arborescens</u>
Golden Current	<u>Ribes aureum</u>
Western Snowberry	<u>Symphoricarpos occidentalis</u>
Silver Buffaloberry	<u>Shepherdia argentea</u>

should always receive some form of mechanical treatment to give it suitable coverage, unless the bed is loose so that natural sloughing of soil will cover the seed. 4/

Natural woodland complexes (woody draws) occur to a minor extent in this study area. These complexes should be avoided during the mining operation, if at all possible, as they are irreplaceable ecosystems which provide nesting cover and feed for the game and non-game animals. If disturbance of these complexes cannot be avoided, the trees and shrubs should be salvaged for transplanting in reconstructed drainages.

Seeding and planting operations should be conducted during the first normal period for favorable planting conditions following the redistribution of suitable plant growth material. In the Pumpkin Creek Study Area, either early spring or late fall planting of grasses and legumes appears most desirable. If spring planting is selected, the plants should be seeded between early March and late April in order that seedlings may emerge before the spring rains begin. If late fall planting is chosen, seeding should be conducted after mid-October to prevent germination.

## POST-RECLAMATION MANAGEMENT

### Responsibility of the Mine Operator

The period of responsibility under the performance bond will begin when the canopy cover of seeded species is comparable to the approved standard 5/ after the last year of seeding, fertilizing, irrigating, or other work. "Comparable to the approved standard" is defined as not significantly less than the approved standard with 90 percent statistical confidence for herbaceous vegetation or 80 percent statistical confidence for trees, shrubs, or half-shrubs. In no case will an area be considered comparable if it is less than 90 percent of the approved standard /Rule IX(15)(b)(i) - Montana Permanent Program/.

The revegetated areas and their respective reference areas will be evaluated for at least two consecutive years prior to application for bond release and shall include the last two consecutive years of the bonding period. Application for bond release may not be submitted prior to the end of the tenth growing season /Rule IX(15)(b)(ii) - Montana Permanent Program/.

On lands restored to rangeland, the reference areas and revegetated areas will both be grazed at a proper level (50 percent or less utilization) for at least the last two years of the bonding period. Vegetation measurements these last two years will be on areas exclosed from grazing by agronomy cages or other systems approved by the Department of State Lands /Rule IX(15)(a)(iv) - Montana Permanent Program/.

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4/ USDA - Forest Service, General Technical Report, INT-64, 1979.

5/ Approved standard refers to an undisturbed "reference area" chosen for comparative purposes to determine success of revegetation on the reclaimed site.

### Responsibility of the Landowner

The landowners in the Pumpkin Creek Study Area will resume responsibility for management of the reclaimed lands following termination of the mine operator's responsibility period. To ensure that the reclaimed land remains stable and productive, the landowners should implement proper range and soil/crop management practices.

On areas restored to rangeland, grazing should be limited to a capacity that the reclaimed land is capable of supporting. Overgrazing reclaimed lands will result in a reduced vegetative cover, accelerated erosion, and an overall decrease in productivity.

On areas returned to cropland, the main objective of the landowner in cultivating the land should be sustained profitable production. To aid in achieving this objective, soil/crop management practices including contour tillage, fertilization, crop rotation, weed and insect control, mulching, etc., should be utilized whenever possible.

### HYDROLOGY RECOMMENDATIONS

The proposed surface mining of the Sawyer-"A" Coalbed in the Pumpkin Creek Study Area will result in some alteration of the ground water, surface water, and geochemical regimes. The following recommendations are designed to mitigate or minimize any deleterious effects.

1. Water wells removed by mining could be replaced by wells of similar or better yield and quality tapping undisturbed aquifers below the Lebo Shale Member of the Fort Union Formation. Springs destroyed during mining could be replaced by wells drilled to deep aquifers below the Lebo Shale Member.

2. Ground water contamination from pollutants or contaminants produced during mining operations could be minimized by not allowing the pollutants to percolate below the mine floor.

3. Toxic materials produced through mining or unearthed by mining could be removed from the mine site or could be isolated between impermeable layers well above the premining water table and away from water courses to minimize the effects of mine spoils on postmining ground water quality.

4. Surface water could be diverted around mine cuts to minimize erosion and/or sediment transport leaving the disturbed areas.

5. Premining reservoirs or natural depressions removed with stripmine overburden could be replaced on spoils to distribute and retard overland flow across potentially erodible materials. Special care to reservoir design could minimize potential leakage through bottom liners to ground water to minimize leaching of soluble salts into underlying ground water bodies.

6. The spoil surface could be shaped, contoured, and prepared to maintain premining quantities of catchment and infiltration characteristics.

7. Surface conditioning of soil could enhance infiltration and maximize utilization of normal precipitation.

#### Future Hydrologic Monitoring

Continued streamflow, ground water level, and water quality monitoring is necessary to resolve seasonal fluctuations and to define the hydrologic system more completely in the study area. Results from the existing monitoring program will constantly be analyzed to determine the need for continued data collection.

Detailed description of water problems that may occur from specific surface mining cuts within the East Pumpkin Creek Coalfield is beyond the scope of this project. An intensive monitoring program would be needed to provide an accurate accounting of the impacts of each mine plan. Such a program would include monitoring water quantity and quality of livestock reservoirs, ephemeral streams, and ground water downgradient from the mine plan from the time of mine planning through reclamation.

## BIBLIOGRAPHY

- American Society for Testing and Materials, 1977, Standard specifications for classification of coals by rank (ASTM designation D-388-77): 1977 Annual book of ASTM standards, pt. 26, p. 214-218.
- Averitt, Paul, 1975, Coal resources of the United States, January 1, 1974: U.S. Geol. Survey Bull. 1412, 131 p.
- Bass, N. W., 1932, The Ashland coal field, Rosebud, Powder River, and Custer Counties, Montana: U.S. Geol. Survey Bull. 831-B, p. 19-105.
- Bentall, Ray, 1963, Methods of determining permeability, transmissibility, and drawdown: U.S. Geol. Survey Water-Supply Paper 1536-I, p. 243-341.
- Brown, Andrew, Culbertson, W. C., Dunham, R. J., Kepferle, R. C., and May, P. R., 1954, Strippable coal in Custer and Powder River Counties, Montana: U.S. Geol. Survey Bull. 995-E, p. 151-199.
- Bryson, R. P., 1951, The Coalwood coal field, Powder River County, Montana: U.S. Geol. Survey Bull. 973-B, p. 23-106.
- Cohen, A. C., 1959, Simplified estimators for the normal distribution when samples are singly censored or truncated: Technometrics, v. 1, no. 3, p. 217-237.
- Connor, J. J., Keith, J. R., and Anderson, B. M., 1976, Trace-metal variation in soils and sagebrush in the Powder River basin, Wyoming and Montana: U.S. Geol. Survey Jour. Research, v. 4, no. 1, p. 49-59.
- DeCarlo, J. A., Sheridan, E. T., and Murphy, Z. E., 1966, Sulfur content of United States coals: U.S. Bur. Mines Inf. Circ. 3212, 44 p.
- Dobbin, C. E., 1929, The Forsyth coal field, Rosebud, Treasure, and Bighorn Counties, Montana: U.S. Geol. Survey Bull. 812-A.
- Ferris, J. G., Knowles, D. B., Brown, R. H., and Stallman, R. W., 1962, Theory of aquifer tests: U.S. Geol. Survey Water-Supply Paper 1536-E, p. 69-174.
- Fieldner, A. C., Rice, W. E., and Moran, H. E., 1942, Typical analyses of coals of the United States: U.S. Bur. Mines Bull. 446, 45 p.
- Francis, Wilfried, 1961, Coal, its formation and composition: London, Edward Arnold (Publishers) Ltd., 806 p.
- Glenn, Marguerite, 1978a, Preliminary geologic map of the Pumpkin Creek EMRIA study site, Box Elder Creek, Leslie Creek, Coalwood, and Olive quadrangles, Powder River County, Montana: U.S. Geol. Survey Open-File Rept. 78-614.

- Glenn, Marguerite, 1978b, Locality and structure contour maps of the Pumpkin Creek EMRIA study site, Powder River County, Montana: U.S. Geol. Survey Open-File Rept. 78-897, 4 maps, 3 section sheets, and tables.
- Groenewold, G. H., and Rehm, R. W., 1980, Instability of Contoured Surface-Mined Landscapes in the Northern Great Plains: Causes and Implications, from: Adequate Reclamation of Mined Lands? - A Symposium, March 26-27, 1980, Billings, MT.
- Hatch, J. R., and Swanson, V. E., 1977, Trace elements in Rocky Mountain coals: Geology of Rocky Mountain Coal -- a symposium (D. K. Murray, editor), Colorado Geol. Survey Resource ser. No. 1, p. 143-165.
- Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water (2d ed.): U.S. Geol. Survey Water-Supply Paper 1473, 363 p.
- Johnson, M. V., and Omang, R. J., 1976, A method for estimating magnitude and frequency of floods in Montana: U.S. Geol. Survey Open-File Rept. 76-650, 35 p.
- Johnson, M. V., Omang, R. J., and Hull, J. A., 1976, Annual peak discharge from small drainage areas in Montana through September 1975: U.S. Geol. Survey open-file report, 205 p.
- Lewis, B. D., and Roberts, R. S., 1977, Geology and water-yielding characteristics of rocks of the northern Powder River Basin, southeastern Montana: U.S. Geol. Survey Open-File Rept. 77-75, 22 p.
- Livingstone, D. A., 1963, Chemical composition of rivers and lakes: U.S. Geol. Survey Prof. Paper 440-G, p. G1-G64.
- Lohman, S. W., 1972, Ground-water hydraulics: U.S. Geol. Survey Prof. Paper 708, 70 p.
- Lowry, H. H., ed., 1945, Chemistry of coal utilization, Volumes I and II: New York, John Wiley and Sons, Inc., 1968 p.
- \_\_\_\_\_, 1963, Chemistry of coal utilization, supplementary volume: New York, John Wiley and Sons, Inc., 1142 p.
- Margaret, G., McAfee, R., et. al., 1972, Glossary of Geology, American Geological Institute, 805 p.
- Matson, R. E., and Blumer, J. W., 1973, Quality and reserves of strippable coal, selected deposits, southeastern Montana: Montana Bur. Mines and Geology Bull. 91, 135 p.
- Matson, R. E., Dahl, G. G., Jr., and Blumer, J. W., 1968, Strippable coal deposits on state land, Powder River County, Montana: Montana Bur. Mines and Geology Bull. 69, 81 p.
- McKee, J. E., and Wolf, H. W., 1963, Water quality criteria: California State Water Quality Control Board Pub. 3-A, 548 p.

- Meisch, A. T., 1967, Methods of computation for estimating geochemical abundances: U.S. Geol. Survey Prof. Paper 574-B, 15 p.
- Montana State Engineer's Office, 1961, Water resources survey - Powder River County, Montana: Helena, Montana, 68 p.
- Montana Department of State Lands, 1980, Rules Pursuant to the Montana Strip and Underground Mine Reclamation Act - Montana Permanent Program, Appendix A.
- Moore, E. S., 1940, Coal, its properties, analysis, classification, geology, extraction, uses, and distribution: New York, John Wiley and Sons, Inc., 473 p.
- Pfleider, E. P., ed., 1968, Surface mining: New York, Am. Inst. Mining, Metall., and Petroleum Engineers, Inc., 1061 p.
- Schopf, J. M., 1960, Field description and sampling of coal beds: U.S. Geol. Survey Bull. 1111-B, 70 p.
- \_\_\_\_\_, 1966, Definitions of peat and coal and of graphite that terminates the coal series (Graphocite): Jour. Geology, v. 74, no. 5, pt. 1, p. 584-592.
- Sindelar, B. W., Hodder, R. L., and Majerus, M. E., 1973, Surface mined land reclamation research in Montana: Montana Agr. Expt. Sta. Research Rept. 40, Montana State Univ., Bozeman, Montana, 122 p.
- Snyder, N. H., 1950, Handbook of coal sampling: U.S. Bur. Mines Tech. Paper 133 (revised), 10 p.
- Swanson, V. E., and Huffman, Claude, Jr., 1976, Guidelines for sample collecting and analytical methods used in the U.S. Geological Survey for determining chemical composition of coal: U.S. Geol. Survey Circ. 735, 11 p.
- Swanson, V. E., Medlin, J. H., Hatch, J. R., Coleman, S. L., Wood, G. H., Jr., Woodruff, S. D., and Hildebrand, R. T., 1976, Collection, chemical analysis, and evaluations of coal samples in 1975: U.S. Geol. Survey Open-File Rept. 76-468, 503 p.
- Swenson, F. A., Miller, W. R., Hodson, W. G., and Visser, F. N., 1976, Maps showing configuration and thickness, and potentiometric surface and water quality in the Madison County, Powder River Basin, Wyoming and Montana: U.S. Geol. Survey Misc. Inv. Map I-847-C.
- Tomkeieff, S. I., 1954, Coals and bitumens and related fossil carbonaceous substances: London, Pergamon Press, Ltd., 122 p.
- Trainer, F. W., 1969, Precipitation and base runoff, Big Pipe Creek basin, Maryland: U.S. Geol. Survey Prof. Paper 650-D, p. D222-D227.

- Trumbull, J.V.A., 1960, Coal fields of the United States, Sheet 1:  
U.S. Geological Survey.
- U.S. Bureau of Mines, 1965, Bituminous coal, in Mineral facts and problems 1965; p. 119-147.
- U.S. Department of Agriculture, Forest Service, 1979, User Guide to Soils, General Technical Report INT-68, 80 p.
- U.S. Department of Agriculture, Forest Service, 1979, User Guide to Vegetation, General Technical Report INT-64, 85 p.
- U.S. Department of Agriculture, Soil Survey Staff, 1951, Soil Survey Manual, Agricultural Handbook, No. 18, 503 p.
- U.S. Department of the Interior, Bureau of Land Management, 1975, Otter Creek Study Site, Montana: EMRIA Report No. 1.
- U.S. Department of the Interior, Bureau of Land Management, 1977, Bear Creek Study Area, Montana, EMRIA Report No. 8.
- U.S. Department of the Interior, Bureau of Land Management, 1977, Otter Creek East Study Site, Montana, EMRIA Report No. 47.
- U.S. Department of the Interior, Bureau of Land Management, 1977, Dam Creek Study Site, Montana, EMRIA Report No. 48.
- U.S. Department of the Interior, Bureau of Land Management, 1978, Chromo/4 Study Site, Montana, EMRIA Report No. 46.
- U.S. Department of the Interior, Bureau of Land Management, 1978, Shy/6 Study Site, Montana, EMRIA Report No. 49.
- U.S. Department of the Interior, Bureau of Land Management, 1978, Newell/28 Study Site, Montana, EMRIA Report No. 50.
- U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement, 1977, Surface Mining Control and Reclamation Act of 1977, Public Law 95-87.
- U.S. Public Health Service, 1962, Drinking water standards, 1962: U.S. Public Health Service Pub. 956, 61 p.
- U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Department of Agriculture Handbook 60, 160 p.
- Van Voast, W.A., 1974, Hydrologic effects of strip coal mining in southeastern Montana -- Emphasis: One year of mining near Decker: Montana Bureau of Mines and Geology Bulletin 93, 24 p.
- Van Voast, W.A., and Hedges, R.B., 1975, Hydrogeologic aspects of existing and proposed strip coal mines near Decker, southeastern Montana: Montana Bureau of Mines and Geology Bulletin 97, 31 p.

Warren, W.C., 1959, Reconnaissance geology of the Birney-Broadus coal field,  
Rosebud and Powder River Counties, Montana: U.S. Geological Survey  
Bulletin 1072-J. p. 561-585 (1960).

APPENDIX A

ENGLISH TO METRIC CONVERSIONS



# ENGLISH TO METRIC (SI) CONVERSIONS

A dual system of measurements--English units and the International System (SI) of metric units--is given in this report. SI is a consistent system of units adopted by the Eleventh General Conference of Weights and Measures in 1960. Selected factors for converting English units to SI units are given below.

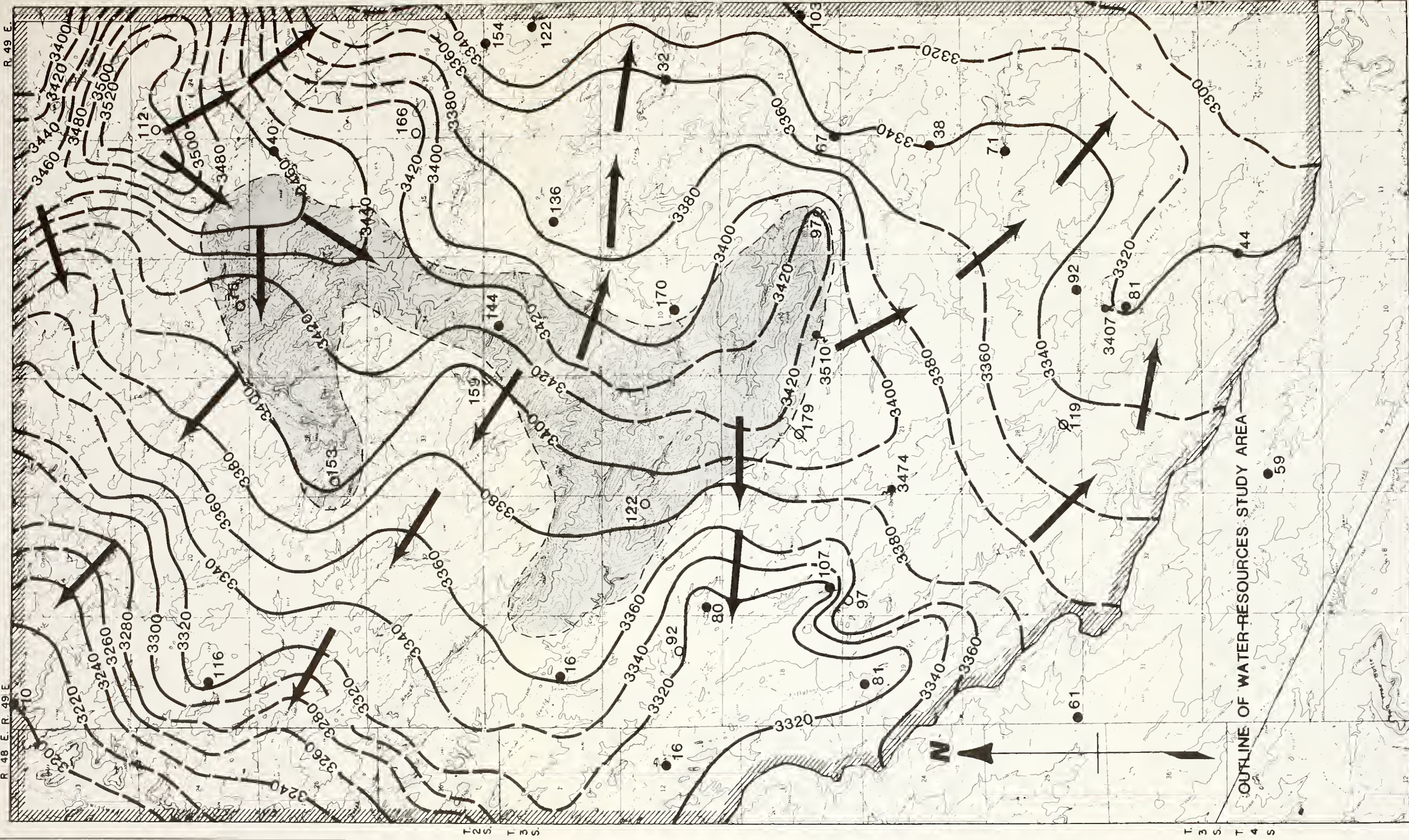
<u>Multiply English Units</u>	<u>By</u>	<u>To Obtain SI Units</u>
Inches	25.40	millimeters (mm)
	2.54	centimeters (cm)
	0.254	decimeters (dm)
	0.0254	meters (m)
Feet	0.3048	meters (m)
Square Feet	0.0929	square meters (m <sup>2</sup> )
Miles	1.609	kilometers (km)
Pounds	453.60	grams (g)
Ton	0.9072	tonne (t)
Acres	0.4047	hectares (ha)
	0.004047	square kilometers (km <sup>2</sup> )
Square miles	2.590	square kilometers (km <sup>2</sup> )
Cubic inches	16.39	cubic centimeters (cm <sup>3</sup> )
Gallons	.003785	cubic meters (m <sup>3</sup> )
Acre-feet	.001233	cubic hectometers (hm <sup>3</sup> )
	1233.00	cubic meters (m <sup>3</sup> )
Feet per mile	0.1894	meters per kilometer (m/km)
Inches per hour	2.54	centimeters per hour (cm/h)
Feet per day	.3048	meters per day (m/d)
Pounds per square inch	70.32	grams per square centimeter (g/cm <sup>2</sup> )
Atmospheres	1033.27	grams per square centimeter (g/cm <sup>2</sup> )
Bars	1019.78	grams per square centimeter (g/cm <sup>2</sup> )
Pounds per cubic foot	0.01602	grams per cubic centimeter (g/cm <sup>3</sup> )
Pounds per acre	1.1206	kilograms per square hectometer (kg/hm <sup>2</sup> )
Feet squared per day	0.0929	meters squared per day (m <sup>2</sup> /d)
Cubic feet per second	0.02832	cubic meters per second (m <sup>3</sup> /s)
Gallons per minute	0.06309	liters per second (l/s)
Cubic feet per second per square mile	0.01093	cubic meters per second per square kilometer $\frac{1}{1.609^2} \frac{(m^3/s)}{km^2}$
Cubic feet per day per square foot	0.3048	cubic meters per day per square meter (m <sup>3</sup> /d)/m <sup>2</sup>
Pounds per square yard per hour	0.5426	kilograms per square meter per hour (kg/m <sup>2</sup> /h)
Pounds per square foot per hour	4.8827	kilograms per square meter per hour (kg/m <sup>2</sup> /h)
Btu per pound	0.556	kilogram calories per kilogram (kcal/kg)
Degree Fahrenheit	$T_c = \frac{T_f - 32}{1.8}$	degrees Celsius (°C)



## APPENDIX B

### GEOLOGY





## EXPLANATION

POTENTIAL SATURATION OF SAWYER-"A" COAL BED--Shows general area where base of Sawyer-"A" coal bed is below potentiometric surface

3020 -- POTENTIOMETRIC CONTOUR--Shows altitude of uppermost continuous ground-water surface, 1975-77. Dashed where approximately located. Contour interval 20 feet. Datum is mean sea level

92 STOCK WELL--Number is depth to water in feet below land surface, 1975-77. Well taps aquifer units within Tongue River Member below Sawyer-"A" coal bed

97 USGS TEST WELL--Number is depth to water, in feet below land surface, 1977. Well obtains water from Sawyer-"A" coal bed or underlying sandstone

159 USGS DRY TEST HOLE--Number is total depth of hole, in feet below land surface

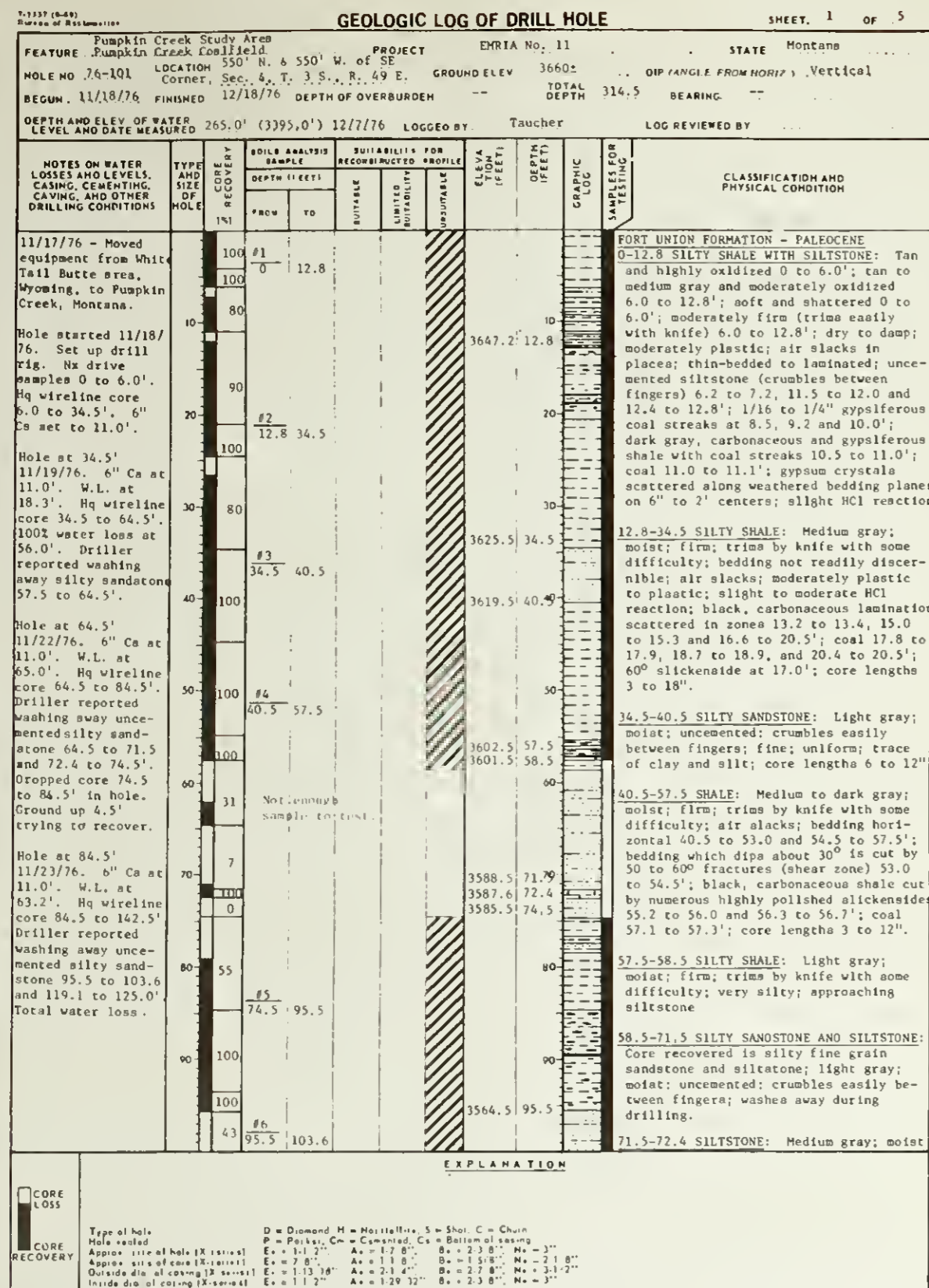
3510 SPRING OR SEEP--Number is altitude of land surface. Datum is mean sea level

Direction of shallow ground-water movement in the Tongue River Number of the Fort Union Formation

PUMPKIN CREEK STUDY AREA  
EAST PUMPKIN CREEK  
COAL FIELD

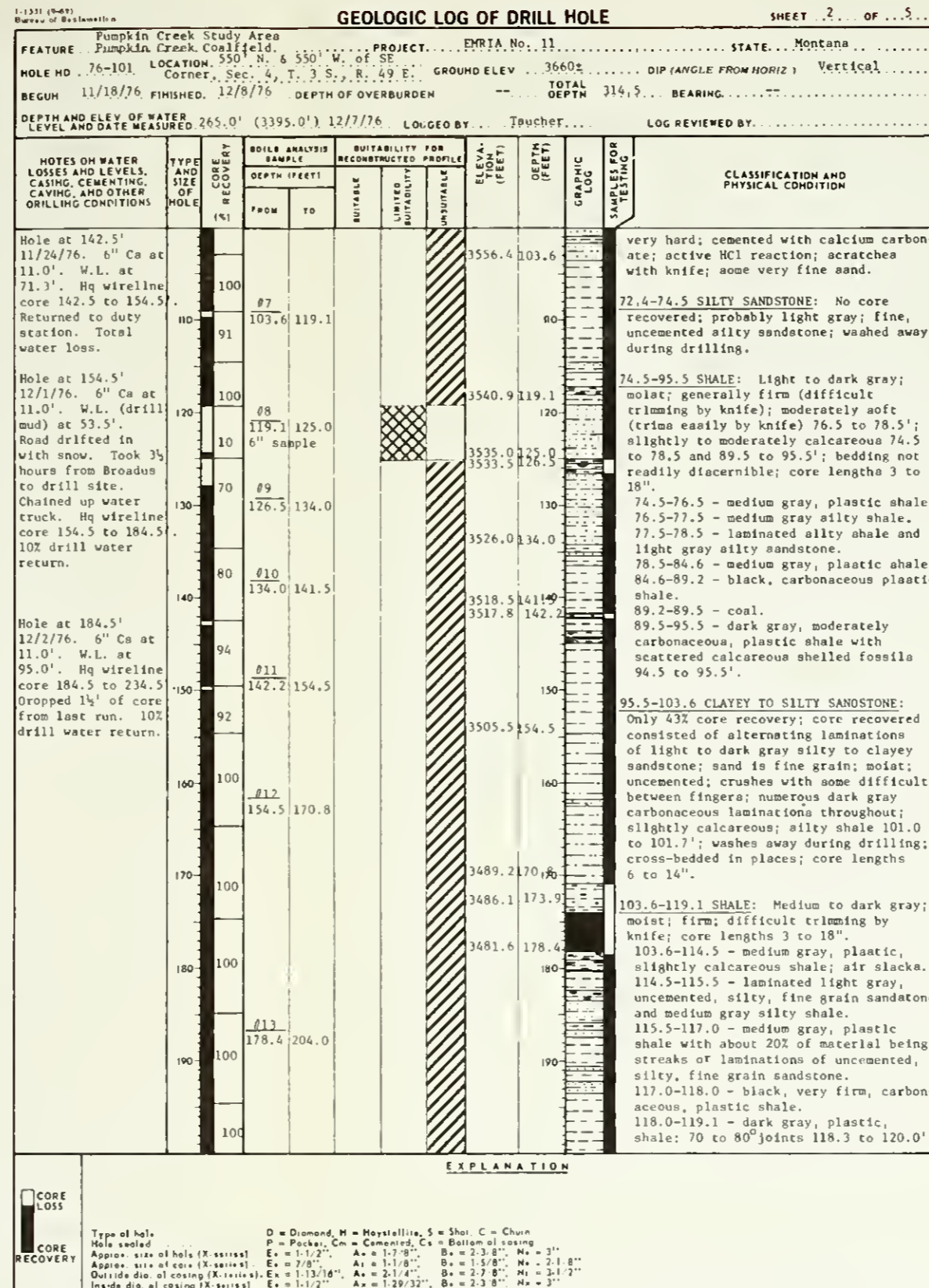
Hydrogeologic Map --  
Potentiometric surface of  
shallow ground water





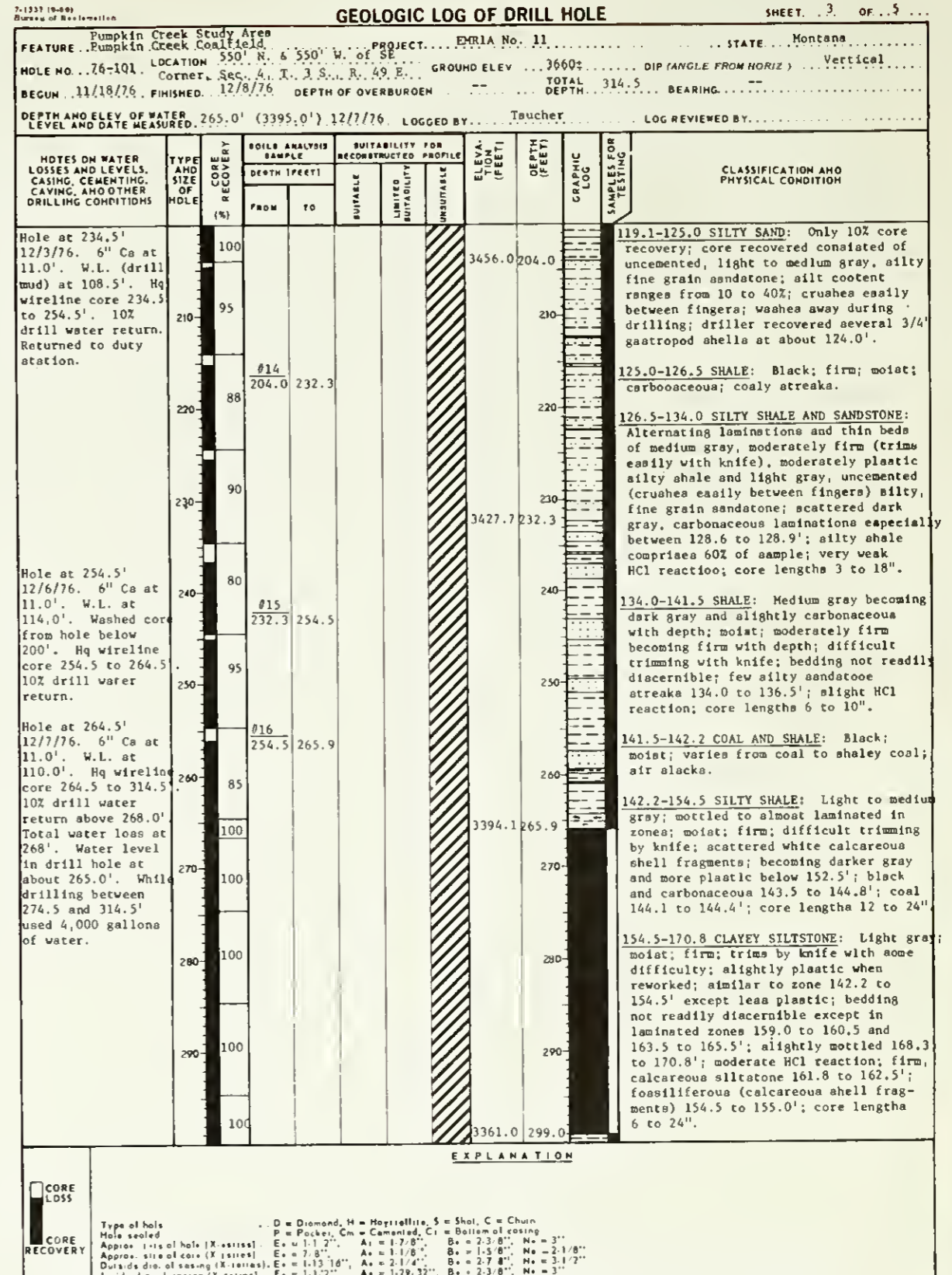
FEATURE Pumpkin Creek Study Area  
Pumpkin Creek Coalfield

PROJECT EMRIA No. 11 STATE Montana SHEET 1 OF 5 HOLE NO 76-101



FEATURE Pumpkin Creek Study Area  
Pumpkin Creek Coalfield

PROJECT EMRIA No. 11 STATE Montana SHEET 2 OF 5 HOLE NO 76-101



FEATURE Pumpkin Creek Study Area  
Pumpkin Creek Coalfield

PROJECT EMRIA No. 11 STATE Montana SHEET 3 OF 5 HOLE NO 76-101



Depth on logs in feet.  
Multiply feet by 0.3048 to obtain meters.

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
WATER AND POWER RESOURCES SERVICE  
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PUMPKIN CREEK STUDY AREA  
PUMPKIN CREEK COALFIELD-MONTANA

**GEOLOGIC LOG OF DH 76-101**

GEOLOGY: G. TAUCHER FIELD APPROVAL: \_\_\_\_\_  
DRAWN: \_\_\_\_\_ TECH. APPROVAL: \_\_\_\_\_  
CHECKED: \_\_\_\_\_ APPROVED: \_\_\_\_\_

BILLINGS, MONTANA SHEET 1 OF 2 FEBRUARY 1981 1305-600-211



7-1317 (4-66)  
Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 5

Pumpkin Creek Study Area Pumpkin Creek Coalfield		PROJECT EMRIA No. 11		STATE Montana								
FEATURE	LOCATION	GROUND ELEV	DIP (ANGLE FROM HORIZ)	Vertical								
HOLE NO 76-101	550' N. & 550' W. of SE Corner, Sec. 4, T. 3 S., R. 49 E.	3660±										
BEGUN 11/18/76	FINISHED 12/8/76	DEPTN OF OVERBURDEN --	TOTAL DEPTH 314.5	BEARING --								
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 265.0' (3395.0') 12/7/76		LOGGED BY Taucher		LOG REVIEWED BY								
NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF NOLE	CORE RECOVERY (%)	BOILE ANALYSIS SAMPLE		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
			DEPTH (FEET)	FROM	TO	SUITABLE	LIMITED SUITABILITY					
Hole at 314.5' 12/8/76. 6" Cs at 11.0'. Pulled 6" Cs and backfilled hole. Started moving equipment to DH 76-102.	100	100	017	299.0	314.5				314.5			170.8-173.9 SHALE: Medium to dark gray and slightly carbonaceous; black and highly carbonaceous 173.4 to 173.9'; moist; silty; laminated; air slacks; core lengths 3 to 12".
												173.9-178.4 COAL: Black; moist; broken; not viable for inspection as coal was sampled and bagged in field.
												178.4-204.0 SHALE WITH SANDSTONE: Shale is dark gray, plastic and moderately firm (trims by knife with some difficulty); sandstone is light gray; fine grain and uncemented (crumbles easily between fingers); moist bedding not apparent in shales; sandstones are laminated; very slight HCl reaction; black and carbonaceous 178.4 to 179.0, 179.1 to 180.2 and 182.5 to 183.4'; coal 179.0 to 179.1 and 180.2 to 180.4'; sandstone 183.5 to 185.8, 186.6 to 187.2, 190.4 to 190.8 and 192.1 to 193.3'; hard, claystone concretion 190.5 to 190.7'; silty and laminated 201.5 to 204.0'; core lengths 3 to 24".
												204.0-232.3 SILTY SHALE AND SILTY SANDSTONE: Alternating laminations and thin beds of medium gray, moderately plastic; moderately soft (cuts easily with knife) silty shale and uncemented, fine grain, light gray, silty sandstone (crumbles easily between fingers); in places sandstone grades to siltstone; moist; weak HCl reaction; silty shale comprises about 60% of sample; hard claystone concretion 212.1 to 212.2'; 4" coal at 222.3'; 60° slickenside at 215.0 and 215.1'; calcareous shale 215.1 to 215.3'; core lengths 3 to 24".
												232.3-265.9 SHALE WITH SILTY SANDSTONE: Shale is medium gray, moist and moderately firm (trims by knife with some difficulty); sandstone is silty, very fine grain and uncemented (crumbles between fingers); moist; slight HCl reaction; 35° fracture at 233.3'; 65° slickenside at 239.5'; sandstone 233.6 to 234.5, 235.8 to 236.0, 237.0 to 238.5, 243.0 to 245.2, 249.5 to 250.9, 257.4 to 259.2 and 260.6 to 260.8'; hard, siliceous siltstone 259.2 to 259.5'; shale is slightly carbonaceous below 264.5'; shales air slack; sandstones tend to wash away during drilling; 3 to 12" core lengths.

## EXPLANATION

CDRE LOSS  
CDRE RECOVERY

Type of hole: D = Diamond, H = Hydrant, S = Shot, C = Churn  
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing  
Approx. size of hole (X-series): Ea = 1-1/2", As = 1-7/8", Ba = 2-3/8", Na = 3"  
Approx. size of core (X-series): Ea = 7/8", As = 1-1/8", Ba = 1-5/8", Na = 2-1/8"  
Outside dia. of casing (X-series): Ea = 1-13/16", As = 2-1/4", Ba = 2-7/8", Na = 3-1/2"  
Inside dia. of casing (X-series): Ea = 1-1/2", As = 1-29/32", Ba = 2-3/8", Na = 3"

Pumpkin Creek Study Area  
Pumpkin Creek Coalfield  
PROJECT EMRIA No. 11  
STATE Montana  
SHEET 4 OF 5  
HOLE NO 76-1017-1317 (4-66)  
Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 5 OF 5

Pumpkin Creek Study Area Pumpkin Creek Coalfield		PROJECT EMRIA No. 11		STATE Montana								
FEATURE	LOCATION	GROUND ELEV	DIP (ANGLE FROM HORIZ)	Vertical								
HOLE NO 76-101	550' N. & 550' W. of SE Corner, Sec. 4, T. 3 S., R. 49 E.	3660±										
BEGUN 11/18/76	FINISHED 12/8/76	DEPTN OF OVERBURDEN --	TOTAL DEPTH 314.5	BEARING --								
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 265.0' (3395.0') 12/7/76		LOGGED BY Taucher		LOG REVIEWED BY								
NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF NOLE	CORE RECOVERY (%)	BOILE ANALYSIS SAMPLE		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
			DEPTH (FEET)	FROM	TO	SUITABLE	LIMITED SUITABILITY					
												265.9-299.0 COAL: Black; moist; slight luster; occasional vertical hairline fractures; only small amount of coal visible for inspection as coal was bagged and sampled in the field.
												299.0-314.5 SILTY SHALE: Light to medium gray; moist; firm; difficult trimming by knife; bedding not readily discernible; weak HCl reaction; uncemented siltstone or clayey siltstone 302.8 to 304.0, 304.5 to 305.5 and 312.0 to 314.0'; hard, cemented claystone 304.0 to 304.5, 305.5 to 306.8, 312.0 to 312.1 and 313.2 to 313.4'; fine grain silty sandstone 314.0 to 314.5'.

## EXPLANATION

CDRE LOSS  
CDRE RECOVERY

Type of hole: D = Diamond, H = Hydrant, S = Shot, C = Churn  
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing  
Approx. size of hole (X-series): Ea = 1-1/2", As = 1-7/8", Ba = 2-3/8", Na = 3"  
Approx. size of core (X-series): Ea = 7/8", As = 1-1/8", Ba = 1-5/8", Na = 2-1/8"  
Outside dia. of casing (X-series): Ea = 1-13/16", As = 2-1/4", Ba = 2-7/8", Na = 3-1/2"  
Inside dia. of casing (X-series): Ea = 1-1/2", As = 1-29/32", Ba = 2-3/8", Na = 3"

Pumpkin Creek Study Area  
Pumpkin Creek Coalfield  
PROJECT EMRIA No. 11  
STATE Montana  
SHEET 5 OF 5  
HOLE NO 76-101Depth on logs in feet.  
Multiply feet by 0.3048 to obtain meters.UNITED STATES  
DEPARTMENT OF THE INTERIOR  
WATER AND POWER RESOURCES SERVICE  
RESOURCE AND POTENTIAL RECLAMATION EVALUATIONPUMPKIN CREEK STUDY AREA  
PUMPKIN CREEK COALFIELD-MONTANA

## GEOLOGIC LOG OF DH 76-101

GEOLOGY: G. TAUCHER  
DRAWN: \_\_\_\_\_  
CHECKED: \_\_\_\_\_  
FIELD APPROVAL: \_\_\_\_\_  
TECH. APPROVAL: \_\_\_\_\_  
APPROVED: \_\_\_\_\_BILLINGS, MONTANA  
SHEET 2 OF 2  
FEBRUARY 1981

1305-600-212



2. 1. 1. 1. (2-4)

## GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE	Pumpkin Creek Study Area Pumpkin Creek Coalfield	PROJECT	EMRIA No. 11	STATE	Montana
HOLE NO.	77-102	LOCATION	1500' N. & 50' E. of SW Corner, Sec. 22, T. 2 S., R. 49 E.	GROUND ELEV.	3520.2
REGIM	12/9/76	FINISHED	8/22/77	DEPTH OF OVERBURDEN	TOTAL DEPTH 154.0
					DIP (ANGLE FROM HORIZ) Vertical
					BEARING

DEPTH AND ELEV. OF WATER 105.2' (3414.8') 8/22/77 LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF MOLE	CORE RECOVERY (%)	ROIL ANALYSIS SAMPLE		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION	
			DEPTH (FEET)		SUITABLE	LIMITED SUITABILITY	UNSUITABLE						
			FROM	TO									
12/9/76 - Set up drill and took Nx drive samples 0-8'.		80						3515.0	5			FORT UNION FORMATION - PALEOCENE	
		100										0-5.0 SANDSTONE AND SHALE: Very weathered; fragmental; oxidized; rusty brown mottled with tan; dry; crumbly; strong HCl reaction.	
1/6/77 - Hole at 8' Hq wireline core 8-11'. Set 6" Cs to 11'.	10	5							10			5.0-17.7 SANDY SILTSTONE: Tan to light gray with rusty bands; dry 5 to 8'; moist 8 to 17.7'; hard 5 to 8'; firm 8 to 17.7'; sandy near top; strong HCl reaction; core lengths to 6".	
Heavy snows in area caused hole to be stopped.		94	#1 11.5	17.0				3502.3 3500.5	17.7 19.5				17.7-19.5 SHALE: Gray; damp; firm; trims with knife with difficulty; plastic; no HCl reaction; core lengths to 8".
8/18/77 - Hole at 11'. 6" Cs at 11'. Hq wireline core 11.0-94.5'. Driller reports grinding up core 36.5 to 44.5'.	20							3496.3 3495.7 3495.2	23.7 24.3 24.8				19.5-23.7 COAL: Black; wet; soft; crumbly.
	30		#2 24.8	44.2						30			23.7-24.3 SHALE: Dark gray; damp; carbonaceous; firm; cuts with knife with difficulty; plastic; no HCl reaction.
		100											24.3-24.8 COAL: Black; wet; soft; crumbly.
8/19/77 - Hole at 94.5'. 6" Cs at 11.0'. W.L. at 45.2'. Hq wireline core 94.5 to 154.0'. About 85% water loss. Driller reports washing away silty sand 140.5 to 144.0'.	40	20						3475.8	44.2				24.8-44.2 SHALE: Gray; damp; firm; barely cuts with knife; carbonaceous 28 to 31.7'; hard & carbonaceous (nearly coal) 34.1 to 34.5'; bedding nearly horizontal; air slacks; no HCl reaction.
8/22/77 - Backfilled hole & moved equipment to DH77-103.	50	100								50			44.2-82.5 SILTY SANDSTONE: Light gray; moist; uncemented; varies from crumbly to firm; fine grained; laminated; some silty fines; strong HCl reaction; core lengths to 18".
	60	100	#3 44.2	66.0						60			82.5-88.5 SANDY SHALE: Gray; damp; firm; barely cuts with knife; contains some very fine sand; plastic; air slacks; bedding nearly horizontal; no HCl reaction; core lengths to 6".
	70	95	#4 66.0	82.5						70			88.5-103.0 COAL: Black; damp; hard; brittle; broken.
	80	95	#5 82.5	88.5				3437.5	82.5				103.0-103.4 SHALE: Gray; damp; hard; somewhat brittle; air slacks; no HCl reaction.
	90	100						3431.5	88.5				103.4-121.0 COAL: Black; damp; hard; brittle; broken.
	100	100								90			121.0-154.0 SILTY, SANDY SHALE: Highly variable; light gray; damp; firm to hard.

		EXPLANATION			
CORE LOSS	Type of hole	D = Diamond, H = Hayastellite, S = Shot, C = Churn			
	Hole sealed	P = Packers, Cm = Cemented, Cs = Bottom of casing			
CORE RECOVERY	Apprx. size of hole (X-series)	Es = 1-1/2", As = 1-7/8"	Bs = 2-3/8"	Ns = 3"	
	Apprx. size of core (X-series)	Es = 7/8", As = 1-1/8"	Bs = 1-5/8"	Ns = 2-1/8"	
	Outside dia. of casing (X-series)	Es = 1-13/16", As = 2-1/4"	Bs = 2-7/8"	Ns = 2-1/2"	
	Inside dia. of casing (X-series)	Es = 1-1/2", As = 1-29/32"	Bs = 2-3/8"	Ns = 3"	

FEATURE Pumpkin Creek Study Area  
Pumpkin Creek Coalfield PROJECT EMRIA No. 11 STATE Montana SHEET 1 OF 2 HDL NO. 77-102

Y. 1337 (4-69)  
Bureau of Reclamation

### GEOLOGIC LOG OF DRILL HOLE

SHEET. . . 2 . . . OF . . . 2

GEOLOGIC LOG OF DRILL HOLE									
Pumpkin Creek Study Area		PROJECT		EMRIA No. 11		STATE		Montana	
Pumpkin Creek Coalfield		LOCATION 1500' N. & 50' E. of SW		CORNER, SEC. 22, T. 2 S., R. 49 E.		GRDUND ELEV		3520.1	
MOLE NO. 77-102		FINISHED 8/22/72		DEPTH OF OVERBURDEN		TOTAL DEPTH		154.0'	
BEGUN 12/9/76		BEARING		Vertical					

DEPTH AND ELEV. OF WATER  
LEVEL AND DATE MEASURED. 105.2' (3414.8') 8/22/77 LOGGED BY Pariah LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
			DEPTH (FEET)		SUITABLE	LIMITED SUITABILITY	UNSUITABLE					
			FROM	TO								
		100						3417.0	103.0			barely trims with knife; laminated bedding nearly horizontal when discernible; contains sandy, silty and clayey zones; clayey zones air alack; strong HCl reaction; core lengths to 2'. 139.0-139.2 - Dark, carbonaceous zone. 140.5-144.0 - Core lost; driller reports silty sand.
		100						3416.6	103.0			
		110							110			
		100										
		170						3399.0	121.0			
		60	86	121.0	140.0				130			
		80							140			
		100	87	140.0	154.0				150			
								3366.0	154.0			
		160							160			
		170							170			
		180							180			
		190							190			

		EXPLANATION			
CORE LOSS	Type of hole . . . . .	D = Diamond, M = Moystellite, S = Shot, C = Churn			
	Hole sealed . . . . .	P = Powder, Cm = Cemented, Ca = Bolt			
CORE RECOVERY	Approx. size of hole (X-series) . .	Es = 1-1/2", Aa = 1-7/8"	Bo = 2-3/8",	Na = 3"	
	Approx. size of core (X-series) . .	Es = 7/8", Aa = 1-1/8"	Bo = 1-5/8",	Ni = 2-1/8"	
	Outside dia. of casing (X-series) .	Es = 1-13/16", Aa = 2-1/4"	Bo = 2-7/8",	Ns = 3-1/2"	
	Outside dia. of casing (X-series) .	Es = 1-13/16", Aa = 2-1/4"	Bo = 2-7/8",	Ns = 3"	

FEATURE	Pumpkin Creek Study Area Pumpkin Creek Coalfield	PROJECT	EMRIA No. 11	STATE	Montana	SHEET	2	OF	2	HOLE NO	77-102...
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Depth on logs in feet.  
Multiply feet by 0.3048 to obtain meters.

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
WATER AND POWER RESOURCES SERVICE  
RESOURCE AND POTENTIAL RECLAMATION EVALUATION  
PUMPKIN CREEK STUDY AREA  
PUMPKIN CREEK COALFIELD-MONTANA

GEOLOGIC LOG OF D.H. 77-102

GEOLOGY L. PARISH FIELD APPROVAL

DRAWN \_\_\_\_\_ TECH APPROVAL \_\_\_\_\_

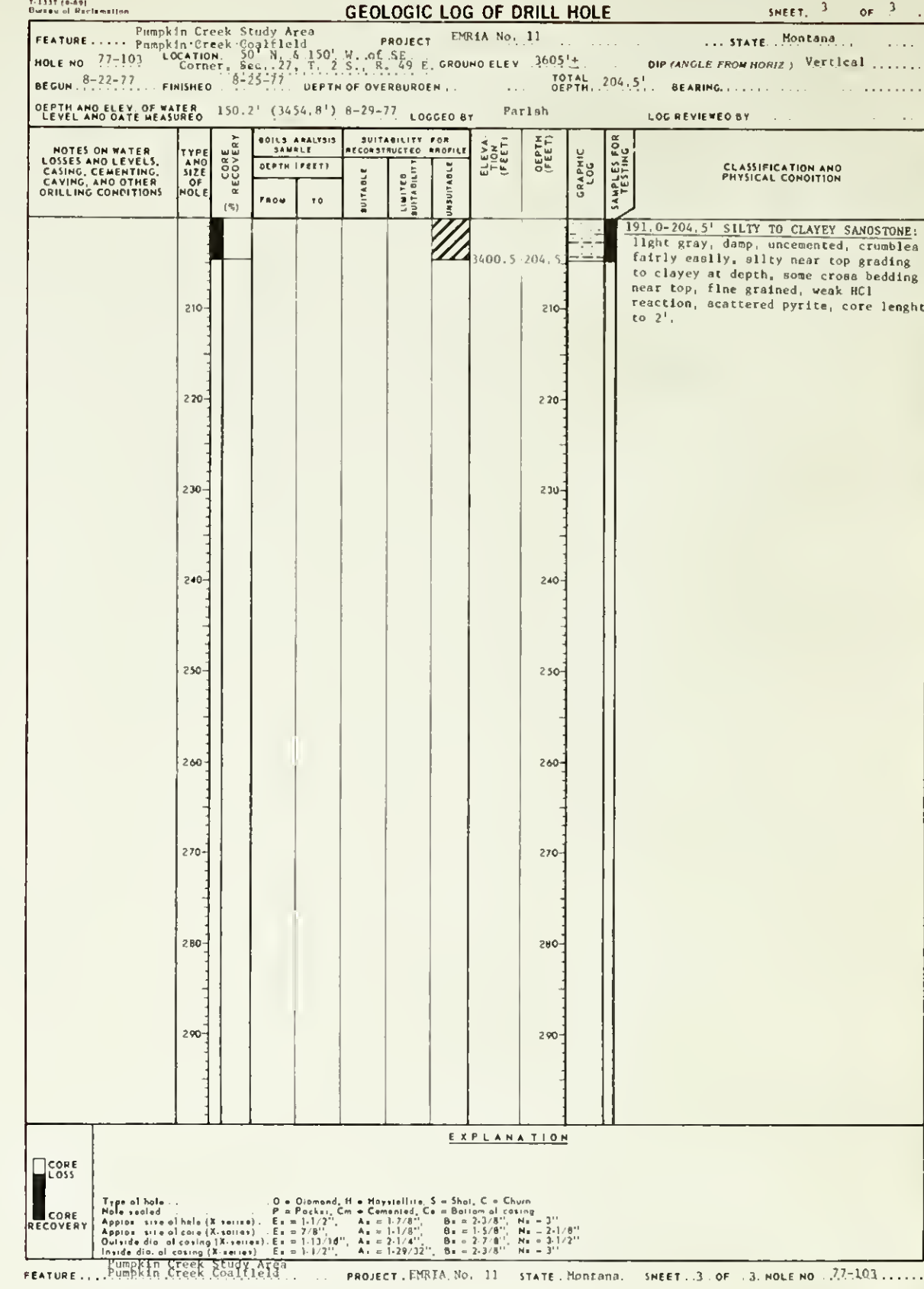
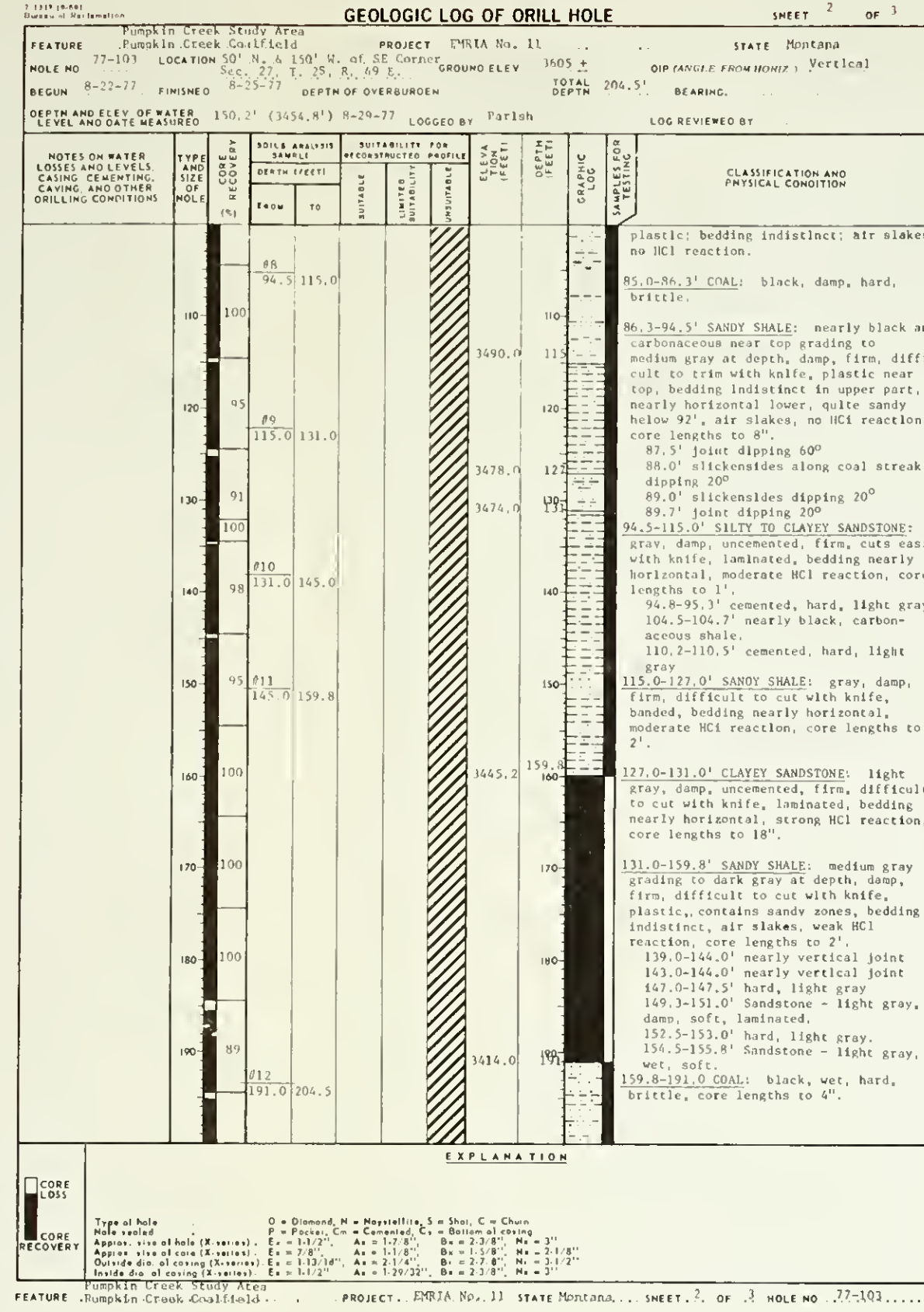
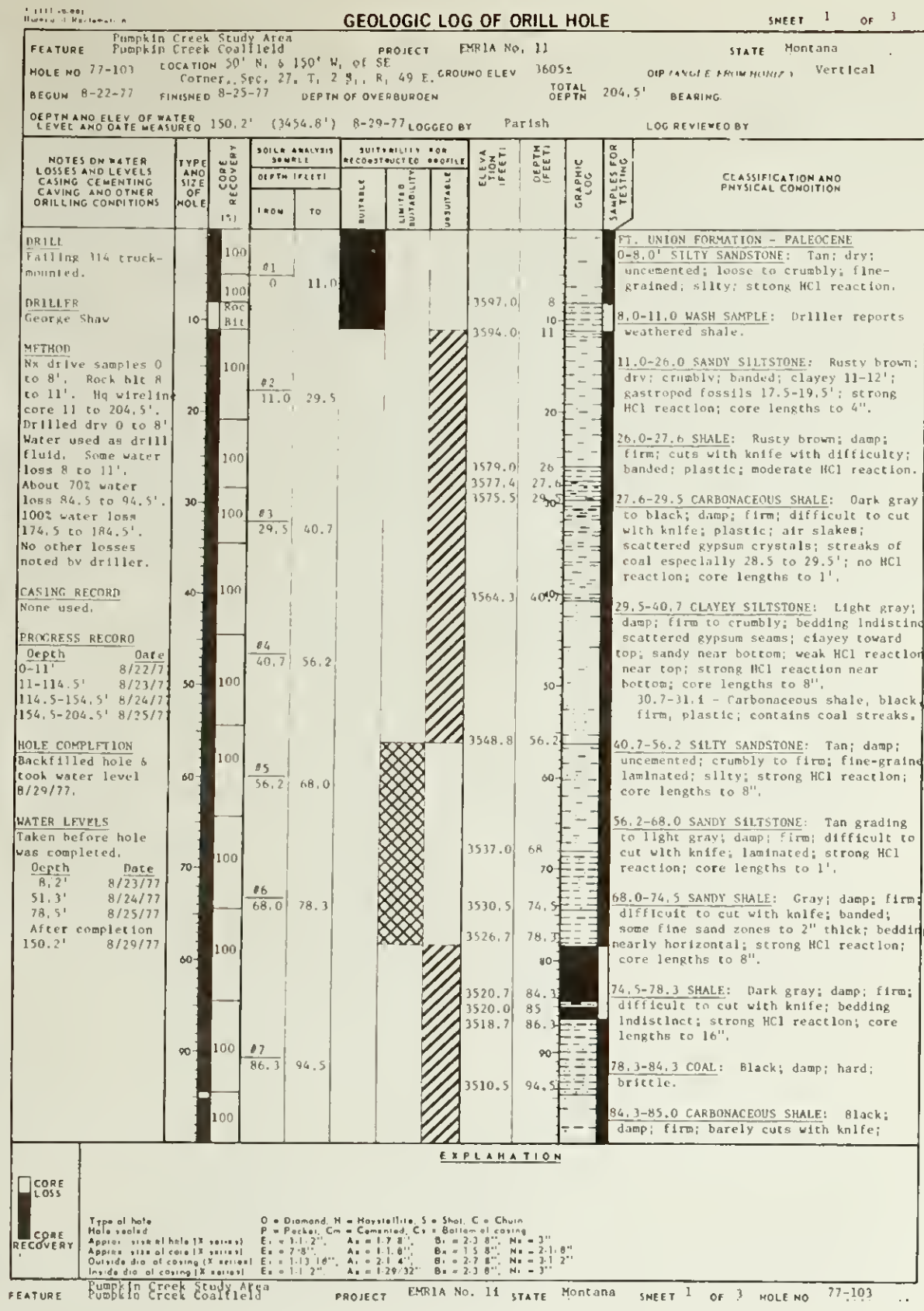
CHECKED \_\_\_\_\_ APPROVED \_\_\_\_\_

CHECKED \_\_\_\_\_

BILLINGS, MONTANA FEBRUARY 1981  
SHEET 1 OF 1

1305-600-213





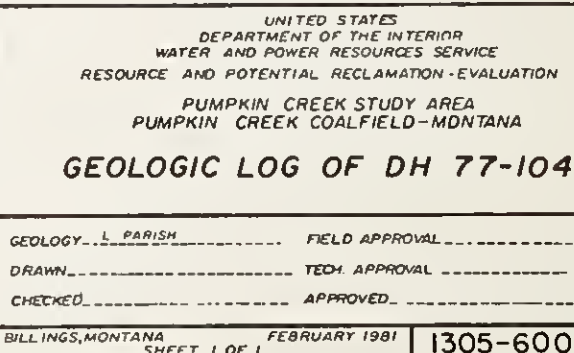
Depth on logs in feet.  
Multiply feet by 0.3048 to obtain meters.

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
WATER AND POWER RESOURCES SERVICE  
RESOURCE AND POTENTIAL RECLAMATION EVALUATION  
PUMPKIN CREEK STUDY AREA  
PUMPKIN CREEK COALFIELD-MONTANA  
**GEOLOGIC LOG OF DH 77-103**

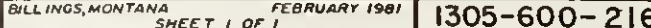
GEOLOGY: L. PARISH FIELD APPROVAL: \_\_\_\_\_  
DRAWN: \_\_\_\_\_ TECH. APPROVAL: \_\_\_\_\_  
CHECKED: \_\_\_\_\_ APPROVED: \_\_\_\_\_

BILLINGS, MONTANA SHEET 1 OF 1 FEBRUARY 1981 1305-600-214











7-1337 (9-69)  
Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Pumpkin Creek Study Area  
Pumpkin Creek Coalfield  
PROJECT EMRIA No. 11 STATE Montana  
HOLE NO 77-106 LOCATION 1200' S. & 350' E. of NW Corner Sec. 20, T. 3S, R. 49E GROUND ELEV 3545' ± DIP (ANGLE FROM HORIZ) Vertical  
BEGUN 9-12-77 FINISHED 9-13-77 DEPTH OF OVERBURDEN TOTAL 164.0' BEARING  
DEPTH AND ELEV. OF WATER 132.5' (3412.5') 9-14-77 LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
			FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE					
DRILL Failing 314 truck-mounted.		100						3543.0	2			FORT UNION FORMATION - PALEOCENE
DRILLER George Shaw		100	#1	0								0-2.0' SILTSTONE: weathered, tan, dry, loose, strong HCl reaction.
METHOD Bx casing drive samples 0-8'. Wash samples 8-11'. Hq wireline core 11-16'. Water used as drill fluid. 50% water loss 124.5-134.5'. 100% loss 134.5-144.0'. No other losses noted.		100		18.4				3527.6	17.8			2.0-17.4' SHALE: weathered, rusty brown, damp, firm, difficult to cut with knife, plastic, bedding not discernible, weak HCl reaction, core lengths to 4". 12.0' Joint dipping 60°.
CASING RECORD None used.		100						3526.6	18.4			17.4-18.4' CLAYEY SANDSTONE: tan, damp, uncemented, firm, crumbles with difficulty, fine grained, bedding not discernible, strong HCl reaction, core lengths to 8".
PROGRESS RECORD Depth Date 0-104.5' 9-12-77 104.5-164.0' 9-13-77		100	#2	18.4				3509.0	36.0			18.4-36.0' SANDY SILTSTONE: tan, damp, firm, difficult to cut with knife, cross bedded, strong HCl reaction, core lengths to 1'. 22.0-24.0' Sandy zone. 28.0' Joint dipping 70°, rusty. 29.0-29.8' Clayey zone, plastic, dark brown, air slakes. 32.0' Joint dipping 70°. 32.5' Joint dipping 70°.
HOLE COMPLETION Backfilled 9-14-77;		90		59.5								36.0-59.5' SANDSTONE: light brown, damp, uncemented, crumbly, laminated, fine grained, bedding appears to dip about 15°, no HCl reaction, core lengths to 5'. 38.5-40.2' Cemented, calcareous, hard, light gray.
WATER LEVELS Depth Date 132.5' 9-14-77		90	#3	36.0								59.5-65.8' SANDY SHALE: dark brown to gray, damp, firm, difficult to cut with knife, bedding not discernible, weak HCl reaction, core lengths to 10". 62.0-62.8' Sandy zone.
		80	#4	59.5				3485.5	59.5			65.8-70.0' SANDSTONE: light brown, moist, uncemented, crumbles easily, fine grained, bedding not discernible, no HCl reaction, core lengths to 4".
		70	#5	70.0				3479.2	65.8			70.0-74.0' SHALE: dark gray, damp, firm, difficult to cut with knife, plastic, bedding not discernible, strong HCl reaction, core lengths to 10".
		60	#6	76.5				3475.0	70.0			74.0-76.5' SANDSTONE: gray-brown, moist, uncemented, crumbles easily, fine grained, strong HCl reaction, bedding not discernible, core lengths to 4".
		50						3471.0	76.5			76.5-95.0' SHALE: gray, damp, firm, difficult to cut with knife, air slakes, bedding not discernible, strong HCl
		40						3468.5	76.5			
		30										
		20										
		10										
		0										

## EXPLANATION

CORE LOSS  
 CORE RECOVERY  
 Type of hole: D = Diamond, H = Hyattellite, S = Shot, C = Churn  
 Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X-series): Ea = 1-1/2", Aa = 1-7/8", Ba = 2-3/8", Na = 3"  
 Approx. size of core (X-series): Ea = 7/8", Aa = 1-1/8", Ba = 1-5/8", Na = 2-1/8"  
 Outside dia. of casing (X-series): Ea = 1-13/16", Aa = 2-1/4", Ba = 2-7/8", Na = 3-1/2"  
 Inside dia. of casing (X-series): Ea = 1-1/2", Aa = 1-29/32", Ba = 2-3/8", Na = 3"

FEATURE Pumpkin Creek Coalfield PROJECT EMRIA No. 11 STATE Montana SHEET 1 OF 2 HOLE NO 77-106

7-1337 (9-69)  
Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE Pumpkin Creek Study Area  
Pumpkin Creek Coalfield  
PROJECT EMRIA No. 11 STATE Montana  
HOLE NO 77-106 LOCATION 1200' S. & 350' E. of NW Corner Sec. 20, T. 3S, R. 49E GROUND ELEV 3545' ± DIP (ANGLE FROM HORIZ) Vertical  
BEGUN 9-12-77 FINISHED 9-13-77 DEPTH OF OVERBURDEN TOTAL 164.0' BEARING  
DEPTH AND ELEV. OF WATER 132.5' (3412.5') 9-14-77 LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
			FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE					
		100	#8	104.5				3440.5	104.5			reaction, core lengths to 10". 77.0-77.5' Sandy zone. 79.0-80.0' Sandy zone. 86.5' Joint dipping 60°. 89.0' Joint dipping 50°.
		100	#9	116.3				3428.7	116.3			95.0-97.0' SANDSTONE: gray, moist, uncemented, crumbles easily, fine grained, bedding not discernible, no HCl reaction, core lengths to 6".
		100		123.5				3421.5	123.5			97.0-104.5' SANDY SHALE: gray, damp, firm, difficult to cut with knife, bedding not discernible, strong HCl reaction, core lengths to 10". 102.0' Joint dipping 60°. 102.9' Slickensides dipping 60°. 103.2' Joint dipping 60°.
		100										104.5-116.3' SILTY SANDSTONE: gray, moist, uncemented, crumbles with difficulty, fine grained, laminated, some crossbedding but most bedding is nearly horizontal, strong HCl reaction, core lengths to 1'. 113.0-113.2' Cemented, hard, light gray.
		100	#10	152.8				3392.2	152.8			116.3-123.5' SHALE: dark gray, damp, firm, difficult to cut with knife, plastic, air slakes, bedding not discernible, no HCl reaction, core lengths to 1'.
		80		164.0				3381.0	164.0			123.5-152.8' COAL: black, damp, hard, brittle, broken.
												152.8-164.0' SILTY SANDSTONE: light gray, moist, uncemented, varies from firm to crumbly, fine grained, laminated, bedding nearly horizontal, very silty near top, no HCl reaction, core lengths to 6".

## EXPLANATION

CORE LOSS  
 CORE RECOVERY  
 Type of hole: D = Diamond, H = Hyattellite, S = Shot, C = Churn  
 Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X-series): Ea = 1-1/2", Aa = 1-7/8", Ba = 2-3/8", Na = 3"  
 Approx. size of core (X-series): Ea = 7/8", Aa = 1-1/8", Ba = 1-5/8", Na = 2-1/8"  
 Outside dia. of casing (X-series): Ea = 1-13/16", Aa = 2-1/4", Ba = 2-7/8", Na = 3-1/2"  
 Inside dia. of casing (X-series): Ea = 1-1/2", Aa = 1-29/32", Ba = 2-3/8", Na = 3"

FEATURE Pumpkin Creek Coalfield PROJECT EMRIA No. 11 STATE Montana SHEET 2 OF 2 HOLE NO 77-106



Depth on logs in feet.  
Multiply feet by 0.3048 to obtain meters.

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
WATER AND POWER RESOURCES SERVICE  
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PUMPKIN CREEK STUDY AREA  
PUMPKIN CREEK COALFIELD-MONTANA

## GEOLOGIC LOG OF DH 77-106

GEOLOGY L. PARISH FIELD APPROVAL  
DRAWN TECH. APPROVAL  
CHECKED APPROVED  
BILLINGS, MONTANA FEBRUARY 1981 SHEET 1 OF 1 1305-600-217



T-1337 (6-69)  
Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

<b>FEATURE</b> Pumpkin Creek Study Area Pumpkin Creek Coalfield <b>LOCATION</b> 550' N., 6 1800' E. of SW Corner Sec. 14, T. 35, R. 49 E. <b>PROJECT</b> EMRIA No. 11 <b>STATE</b> Montana <b>HOLE NO.</b> 77-107 <b>GROUND ELEV.</b> 3570' + <b>DIP (ANGLE FROM HORIZ.)</b> Vertical <b>BEGUN</b> 9-14-77 <b>FINISHED</b> 9-15-77 <b>DEPTH OF OVERBURDEN</b> <b>DEPTH</b> 164.5' <b>BEARING</b>									
<b>DEPTH AND ELEV. OF WATER</b> 113.6' (3456.4') 9-16-77 <b>LOGGED BY</b> Parish <b>LOG REVIEWED BY</b>									
NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOIL ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)
			FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE		
<b>DRILL</b> Falling 314 truck-mounted. <b>DRILLER</b> George Shaw <b>METHOD</b> Bx casing drive samples 0-9'. Wash samples 9-11'. Hq wireline core 11-164.5'. Water used as drill fluid. 50% water loss 24.5-34.5'. 10% water loss 34.5-124.5'. 50% water loss 124.5-134.5'. 95% water loss 134.5-164.5'. No other losses noted. <b>CASING RECORD</b> None used. <b>PROGRESS RECORD</b> Depth Date 0-94.5' 9-14-77 94.5-164.5' 9-15-77 <b>HOLE COMPLETION</b> Backfilled 9-16-77 <b>WATER LEVELS</b> Depth Date 113.6' 9-16-77									
<b>EXPLANATION</b> Type of hole: D = Diamond, H = Hyattellite, S = Shot, C = Churn Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3" Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8" Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2" Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"									

**FEATURE** Pumpkin Creek Study Area  
Pumpkin Creek Coalfield  
**PROJECT** EMRIA No. 11 **STATE** Montana **SHEET** 1 **OF** 2 **HOLE NO.** 77-107
T-1337 (6-69)  
Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

<b>FEATURE</b> Pumpkin Creek Study Area Pumpkin Creek Coalfield <b>LOCATION</b> 550' N., 6 1800' E. of SW Corner Sec. 14, T. 35, R. 49 E. <b>PROJECT</b> EMRIA No. 11 <b>STATE</b> Montana <b>HOLE NO.</b> 77-107 <b>GROUND ELEV.</b> 3570' + <b>DIP (ANGLE FROM HORIZ.)</b> Vertical <b>BEGUN</b> 9-14-77 <b>FINISHED</b> 9-15-77 <b>DEPTH OF OVERBURDEN</b> <b>DEPTH</b> 164.5' <b>BEARING</b>									
<b>DEPTH AND ELEV. OF WATER</b> 113.6' (3456.4') 9-16-77 <b>LOGGED BY</b> Parish <b>LOG REVIEWED BY</b>									
NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOIL ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)
			FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE		
<b>EXPLANATION</b> Type of hole: D = Diamond, H = Hyattellite, S = Shot, C = Churn Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3" Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8" Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2" Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"									

**FEATURE** Pumpkin Creek Study Area  
Pumpkin Creek Coalfield  
**PROJECT** EMRIA No. 11 **STATE** Montana **SHEET** 2 **OF** 2 **HOLE NO.** 77-107

Depth on logs in feet.  
Multiply feet by 0.3048 to obtain meters.

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
WATER AND POWER RESOURCES SERVICE  
RESOURCE AND POTENTIAL RECLAMATION EVALUATION  
PUMPKIN CREEK STUDY AREA  
PUMPKIN CREEK COALFIELD-MONTANA  
**GEOLOGIC LOG OF DH 77-107**

GEOLOGY	FIELD APPROVAL
DRAWN	TECH. APPROVAL
CHECKED	APPROVED
BILLINGS, MONTANA FEBRUARY 1981 SHEET 1 OF 1	
1305-600-218	



# GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

7-1336 (6-68) Bureau of Reclamation		<b>GEOLOGIC LOG OF DRILL HOLE</b>		SHEET <u>1</u> OF <u>2</u>	
FEATURE	Pumpkin Creek Study Area Pumpkin Creek Coalfield	PROJECT ENR1A No. 11	STATE Montana		
NOLE NO	77-108	LOCATION 2550' N. & 1650' E. of SW Corner Sec. 8, T. 3 S., R. 49 E.	GROUND ELEV 3475'±	DIP (ANGLE FROM HORIZ.) Vertical	
BEGIN	9-19-77	FINISHED 9-21-77	DEPTH OF OVERBURDEN	TOTAL DEPTH 136.0'	BEARING
DEPTH AND ELEV. OF WATER MEASURED	83.5' (391.5')	9-22-77	LOGGED BY Parish	LOG REVIEWED BY	

[illegible]

### EXPLANATION

CORE LOSS	Type of halo		O = Diamond, N = Hayastillite, S = Shot, C = Churn
	Nuclei sealed		P = Pecker, Cm = Cemented, Cs = Bottom of casing
CORE RECOVERY	Approx. area of hole (X-series)		E = 1:1.2', Aa = 1:7.8', Ba = 2:3.8', Nc = 3:1'
	Approx. area of bore (X-series)		E = 7:8', Aa = 1:8.8', Ba = 2:7.8', Nc = 3:1'
	Outside dia. of casing (X-series)		E = 1.3/16", Aa = 2:1.4', Ba = 2:7.8', Nc = 3:1'
	Inside dia. of casing (X-series)		E = 1:1.2/2", Aa = 1:29/32", Ba = 2:3.8', Nc = 3:1'

FEATURE	Pumpkin Creek Study Area Pumpkin Creek Coalfield	PROJECT	ENRJA No. 11	STATE	Montana	SHEET	1 OF 2	NOTE NO	77-108
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## GEOLOGIC LOG OF DRILL HOLE

SHEET. 2. OF 2.

<div style="display: flex; justify-content: space-between;"> <span>1-1327 (6-69) Bureau of Reclamation</span> <span><b>GEOLOGIC LOG OF DRILL HOLE</b></span> <span>SHEET <u>2</u> OF <u>2</u></span> </div>					
FEATURE	Pumpkin Creek Study Area Pumpkin Creek-Coalfield	PROJECT	EMRIA No. 11	STATE	Montana
HOLE NO.	77-108	LOCATION	2550' N. of SW Corner Sec. 8, T. 3 S., R. 49 E.		
BEGUN	9-19-77	FINISHED	9-21-77	DEPTH OF OVERBURDEN	
DEPTHS AND ELEV. OF WATER LEVEL AND GATE MEASURED	83.5' (3391.5')	9-22-77	LOGGED BY	Rutish	LOG REVIEWED BY

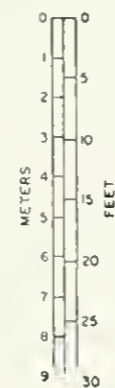
NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF NOLE	CORE RECOVERY (%)	BOLE ANALYSIS SAMPLE		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
			DEPTH (FEET)		EUTABLE	LIMITED SUITABILITY	UNSUITABLE					
			FROM	TO								
		100										
		100							110			
		100						3356.3	118.7			
		100	85	118.7	134.0			3350.4	124.6			
		100							130			
								3341.0	134.0			
									140			
									150			
									160			
									170			
									180			
									190			

## EXPLANATION

CORE LOSS		CORE RECOVERY	
Type of hole	O = Olomand, N = Nagastellit, S = Shot, C = Chain		
Nets sealed	P = Pocker, Cm = Cemented, Cs = Bottom of casing		
Approx. size of hole (X=series)	E = 1-1/2", A = 1-7/8", B = 2-3/8", H = 3"		
Approx. size of hole (K=series)	E = 7/8", A = 1-1/8", B = 1-5/8", H = 2"		
Outside dia. of casing (X=series)	E = 1-1/2", A = 2-1/4", B = 2-7/8", H = 3-1/2"		
Inside dia. of casing (X=series)	E = 1-1/2", A = 1-29/32", B = 2-3/8", H = 3"		

Inside dia. of casing (X-series) Ea = 1-1/2", A1 = 1-29/32", Da = 2-3/8", H1 = 3"

FEATURE... Pumpkin Creek Study Area  
Pumpkin Creek Coalfield..... PROJECT... EMRIA No. 11, STATE Montana SHEET 2. OF 2 HOLE NO. 77-108.....



Depth on logs in feet.  
Multiply feet by 0.3048 to obtain meters.

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
WATER AND POWER RESOURCES SERVICE  
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PUMPKIN CREEK STUDY AREA  
PUMPKIN CREEK CDALFIELD-MDNTANA

## GEOLOGIC LOG OF DH 77-108

GEOLOGY L. PARISH FIELD APPROVAL \_\_\_\_\_  
DRAWN \_\_\_\_\_ TECH. APPROVAL \_\_\_\_\_  
CHECKED \_\_\_\_\_ APPROVED \_\_\_\_\_

BILLINGS, MONTANA      FEBRUARY 1981      1305-600-219  
SHEET 1 OF 1



7-1337 (8-88)  
Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

Pumpkin Creek Study Area  
Pumpkin Creek Coalfield  
PROJECT EMRIA No. 11 STATE Montana  
HOLE NO. 77-109 LOCATION 1850' N. & 25' W. of SE Corner Sec. 2, T. 3 S., R. 49 E. GROUND ELEV. 3545'± DIP (ANGLE FROM HORIZ.) Vertical  
BEGUN 9-22-77 FINISHED 9-27-77 DEPTH OF OVERBURDEN TOTAL DEPTH 142.5' BEARING  
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 56.5' (3488.5') 9-27-77 LOGGED BY: Parish LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE				ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
			FROM	TO	SUITABLE	LIMITED SUITABILITY	UNUSABLE						
DRILL Failing 314 truck-mounted.		100											FORT UNION FORMATION - PALEOCENE
DRILLER George Shaw		100	#1	0									0-11.3' SHALE: highly weathered, tan, dry to damp at depth, crumbled, bedding not discernible, some caliche 0-6', strong HCl reaction. Note: Wash sample 10-11'.
METHOD Bx casing drive samples 0-10'. Wash sample 10-11'. Hq wireline core samples 11-142.5'. Water used as drill fluid. 10% water loss 0-83.5'. 20% water loss 83.5-142.5'.		42							3533.7	11.3			11.3-15.0' CARBONACEOUS SHALE: dark rusty brown with black zones, moist, soft, cuts easily with knife, plastic, bedding not discernible, no HCl reaction, core lengths to 3'.
CASING RECORD None used.		62	#2	17.5					3527.5	17.5			15.0-17.5' COAL: poor recovery, most washed away during drilling, black, moist, very soft and crumbled.
PROGRESS RECORD Depth Date 0-10' 9-22-77 Rained 9-22-77 most of day -- 10-102.5' 9-26-77 102.5-142.5' 9-27-77		90							3519.5	25.5			17.5-20.0' CARBONACEOUS SHALE: dark rusty brown with black zones, moist, soft, cuts easily with knife, plastic, a few thin coal layers, scattered gypsum crystals, bedding not discernible, no HCl reaction, core lengths to 3'.
HOLE COMPLETION Backfilled.		96	#3	34.0					3519.0	26			20.0-34.0' SANDY SHALE: gray, damp, firm, but cuts easily with knife, plastic, air slakes, bedding nearly horizontal, weak HCl reaction, core lengths to 1'.
WATER LEVELS Depth Date 56.5' 9-27-77 Taken before hole was completed.		95							3511.0	34			25.5-26.0' COAL, black, moist, hard, brittle. 28.0-30.0' Sandy zone, laminated.
		95							3502.0	41			34.0-43.0' CLAYEY SANDSTONE: gray, damp, uncemented, firm, crumbles with difficulty, fine grained, laminated, bedding nearly horizontal, moderate HCl reaction, core lengths to 1'.
		81	#5	62.0					3494.8	50			43.0-50.2' SHALE: gray, damp, firm, difficult to cut with knife, plastic, air slakes, bedding not discernible, no HCl reaction, core lengths to 1'.
		100							3493.0	52			48.2-48.3' Carbonaceous
		100							3488.3	56.7			50.2-52.0' SANDSTONE: light gray, damp, uncemented, crumbles easily, fine grained, laminated, moderate HCl reaction, bedding nearly horizontal, core lengths to 6".
		100							3486.0	59			52.0-56.7' SANDY SHALE: gray, damp, firm, difficult to cut with knife, bedding not discernible, strong HCl reaction, core lengths to 10".
		100							3483.0	62			56.7-59.0' SILTY SANDSTONE: gray, moist, uncemented, crumbles easily, fine grained, laminated, bedding nearly horizontal, core lengths to 4".
		100							3479.0	66			
		100							3475.0	70			
		100							3470.0	75			
		100							3462.5	82.5			

## EXPLANATION

CORE LOSS	Type of hole	D = Diamond, H = Hyattelite, S = Shot, C = Churn
CORE RECOVERY	Hole sealed	P = Packer, Cm = Cemented, Cs = Bottom of casing
	Approx. size of hole (X-series)	Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
	Approx. size of core (X-series)	Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
	Outside dia. of casing (X-series)	Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
	Inside dia. of casing (X-series)	Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Pumpkin Creek Study Area PROJECT EMRIA No. 11 STATE Montana SHEET 1 OF 2 HOLE NO. 77-109

7-1337 (8-88)  
Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

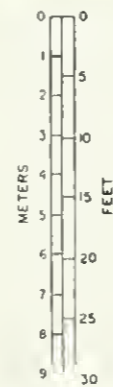
Pumpkin Creek Study Area  
Pumpkin Creek Coalfield  
PROJECT EMRIA No. 11 STATE Montana  
HOLE NO. 77-109 LOCATION 1850' N. & 25' W. of SE Corner Sec. 2, T. 3 S., R. 49 E. GROUND ELEV. 3545'± DIP (ANGLE FROM HORIZ.) Vertical  
BEGUN 9-22-77 FINISHED 9-27-77 DEPTH OF OVERBURDEN TOTAL DEPTH 142.5' BEARING  
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 56.5' (3488.5') 9-27-77 LOGGED BY: Parish LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE				ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
			FROM	TO	SUITABLE	LIMITED SUITABILITY	UNUSABLE						
		100											59.0-62.0' SHALE: gray, damp, firm, difficult to cut with knife, plastic, air slakes, strong HCl reaction, bedding not discernible, core lengths to 18".
		100											62.0-66.0' SANDSTONE: gray, moist, uncemented, soft, crumbled, fine grained, bedding not discernible, strong HCl reaction.
		100	#6	116.3					3428.7	116.3			66.0-70.0' SHALE: gray, damp, firm, difficult to cut with knife, air slakes, bedding not discernible, strong HCl reaction, core lengths to 1'.
		100											67.5-67.8' Siltstone-hard, tan.
		100	#7	130.0									70.0-75.0' SANDSTONE: gray, moist, uncemented, crumbles easily, fine grained, laminated, bedding nearly horizontal, moderate HCl reaction, core lengths to 4".
		100											71.6-71.9' Shale-dark gray.
		100											71.9-72.2' Sandstone-hard, tan.
		100											74.7-75.0' Sandstone-hard, tan.
		100							3402.5	142.5			75.0-82.5' SHALE: gray, damp, firm, difficult to cut with knife, plastic, air slakes, weak to moderate HCl reaction, bedding not discernible, core lengths to 18".
		100											76.8-77.7' Sandy zone.
		100											82.5-116.3' COAL: black, moist, hard, brittle, core lengths to 6".
		100											97.0-97.6' Shale-gray, plastic.
		100											116.3-142.5' SANDY SILTSTONE: light gray, damp, firm to hard, will barely trim with knife, laminated, bedding nearly horizontal, moderate to strong HCl reaction, core lengths to 2'.
		100											116.3-120.0' Scattered, thin carbonaceous lenses.
		100											129.5-130.0' Carbonaceous.

## EXPLANATION

CORE LOSS	Type of hole	D = Diamond, H = Hyattelite, S = Shot, C = Churn
CORE RECOVERY	Hole sealed	P = Packer, Cm = Cemented, Cs = Bottom of casing
	Approx. size of hole (X-series)	Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
	Approx. size of core (X-series)	Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
	Outside dia. of casing (X-series)	Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
	Inside dia. of casing (X-series)	Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Pumpkin Creek Study Area PROJECT EMRIA No. 11 STATE Montana SHEET 2 OF 2 HOLE NO. 77-109



UNITED STATES  
DEPARTMENT OF THE INTERIOR  
WATER AND POWER RESOURCES SERVICE  
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PUMPKIN CREEK STUDY AREA  
PUMPKIN CREEK COALFIELD-MONTANA

## GEOLOGIC LOG OF DH 77-109

GEOLOGY: L. PARISH FIELD APPROVAL  
DRAWN: TECH. APPROVAL  
CHECKED: APPROVED

BILLINGS, MONTANA FEBRUARY 1981 SHEET 1 OF 1 1305-600-220



# WEATHERING TESTS

## Overburden Samples From Pumpkin Creek, Montana

Sample I.D.	Remarks
Shale DH 76-101 Depth (ft) 22.5-23.5 (PC-1)*	See Photographs 6 and 9  <u>Laboratory weathering:</u> Slaking at 5 cycles; continued slaking at 20 cycles. %BD = 43 <u>Outdoor:</u> Severe slaking at 1 year. %BD = 100
Siltstone DH 76-101 Depth (ft) 39.0-40.0 (PC-2)	Sample not tested. It was already broken down when received. %BD = 100
Shale/Siltstone DH 76-101 Depth (ft) 102.0-102.8 (PC-3)	See Photographs 6 and 9  <u>Laboratory weathering:</u> Surface slaking at 5 cycles; peeling at 20 cycles. %BD = 5 <u>Outdoor:</u> Slaking and peeling at 1 year. %BD = 48
Shale DH 76-101 Depth (ft) 137.5-138.5 (PC-4)	See Photographs 7 and 9  <u>Laboratory weathering:</u> Slight surface slaking at 10 cycles; continued slaking at 20 cycles. %BD = 11 <u>Outdoor:</u> Severe slaking and cracking at 1 year. %BD = 100
Shale DH 76-101 Depth (ft) 197.0-198.8 (PC-5)	See Photographs 7 and 10  <u>Laboratory weathering:</u> Slight surface slaking at 10 cycles; continued slaking at 20 cycles. %BD = 15 <u>Outdoor:</u> Slaking at 1 year %BD = 50

Sample I.D.	Remarks
Siltstone DH 76-101 Depth (ft) 249.8-250.8 (PC-6)	See Photographs 8 and 10  <u>Laboratory weathering:</u> Slight surface slaking at 20 cycles. %BD = 0 <u>Outdoor:</u> Very slight scouring at 1 year %BD = 5
Composite sample DH 76-101 Depth (ft) 0-257 (PC-7)	See Photographs 11 through 14  <u>Laboratory weathering:</u> Very little break- down of composite sample at 20 cycles. <u>Outdoor:</u> Considerable breakdown of specimen after one-year outdoor exposure.

Photograph 6



a. Original condition of test specimens



b. Condition of test specimens after weathering

Photo 6 -- Results of weathering tests for shale sample PC-1 and shale/siltstone sample PC-3. Specimens A subjected to 10 laboratory weathering cycles; specimens B subjected to 15 weeks of outdoor exposure.



Photograph 7



a. Original condition of test specimens

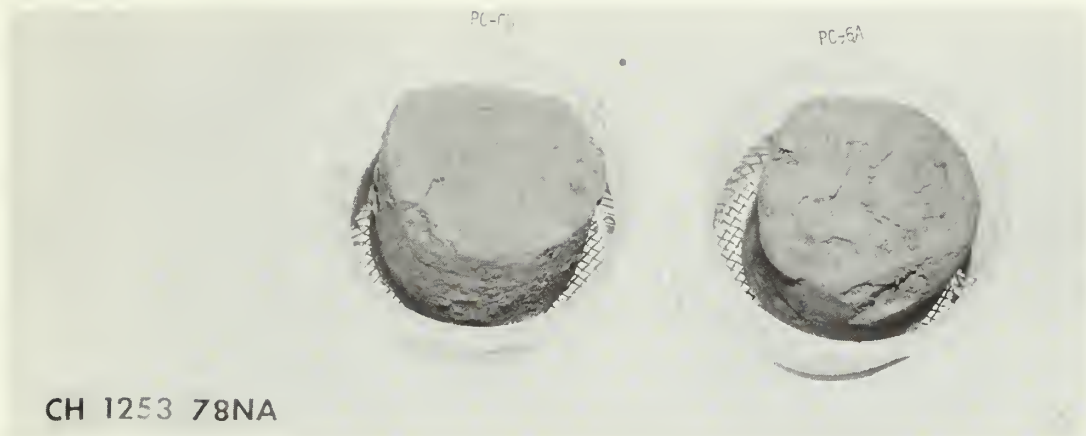


b. Condition of test specimens after weathering

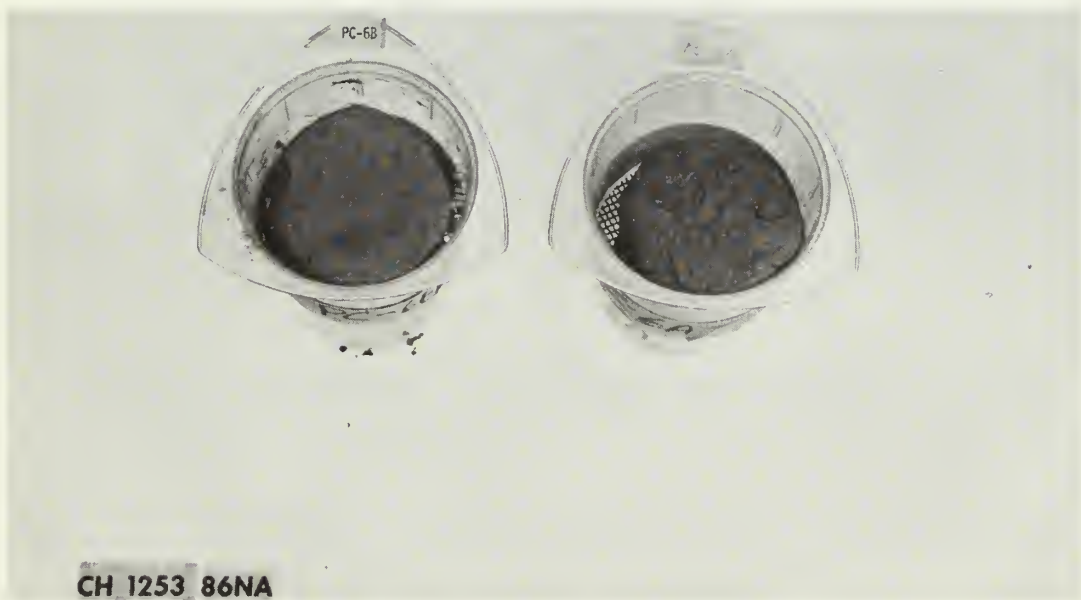
Photo 7 - - Results of weathering tests for shale samples PC-4 and PC-5  
Specimens A subjected to 20 laboratory weathering cycles; specimens B  
subjected to 15 weeks of outdoor exposure



Photograph 8



a. Original condition of test specimens.



b. Condition of test specimens after weathering.

Photo 8 — — Results of weathering tests for siltstone sample PC-6. Specimens A subjected to 20 laboratory weathering cycles; specimens B subjected to 15 weeks of outdoor exposure.



Photograph 9

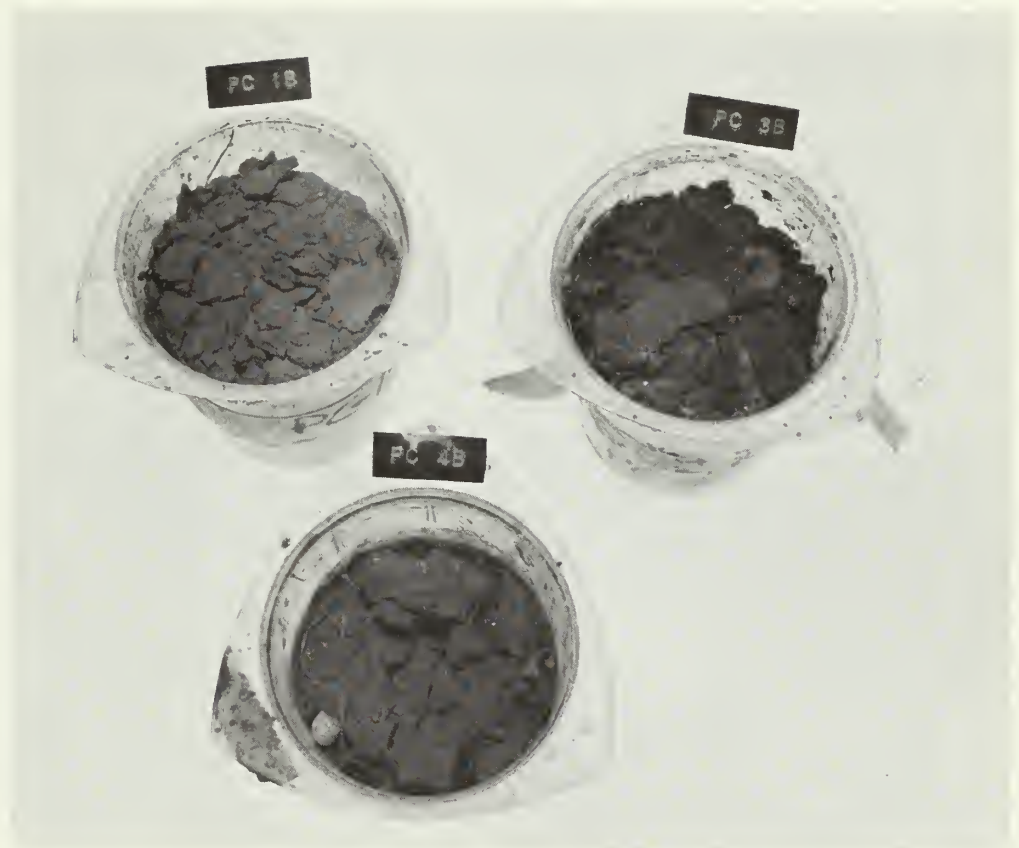


Photo 9 — Results of one-year outdoor exposure tests for Specimens PC-1B, PC-3B, and PC-4B



Photograph 10

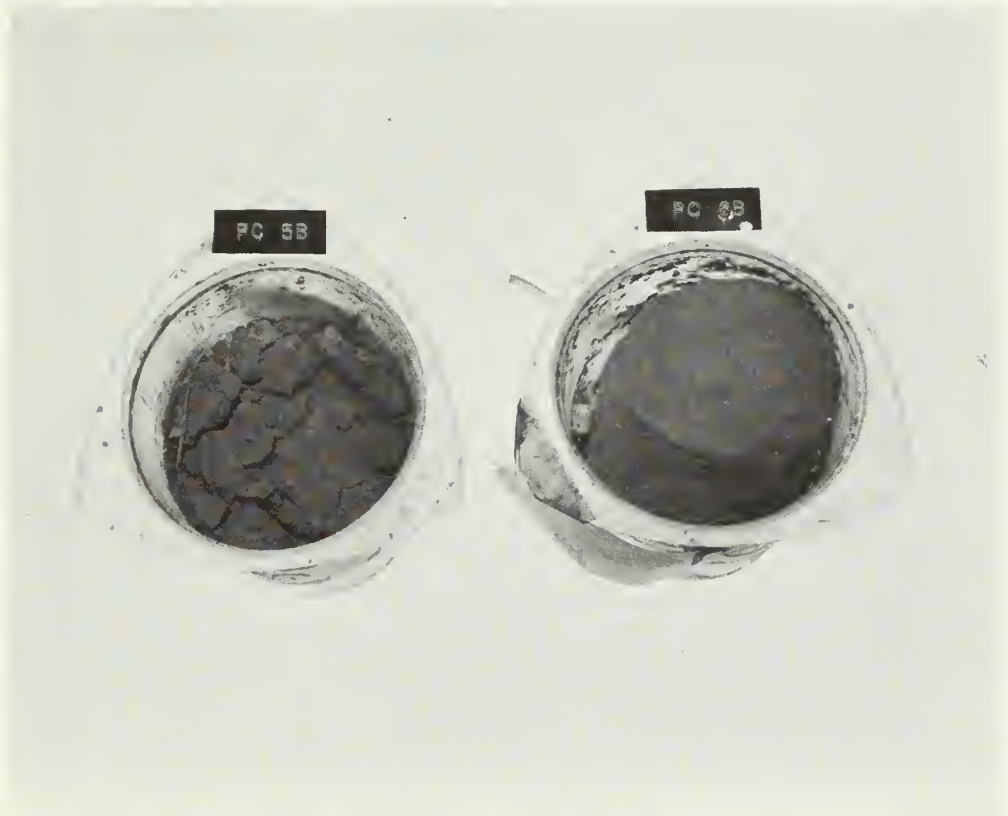


Photo 10- - Results of one-year outdoor exposure tests for Specimens PC-5B and PC-6B



Photograph 11



Photo 11-- — Original condition of composite sample PC-7A



Photograph 12

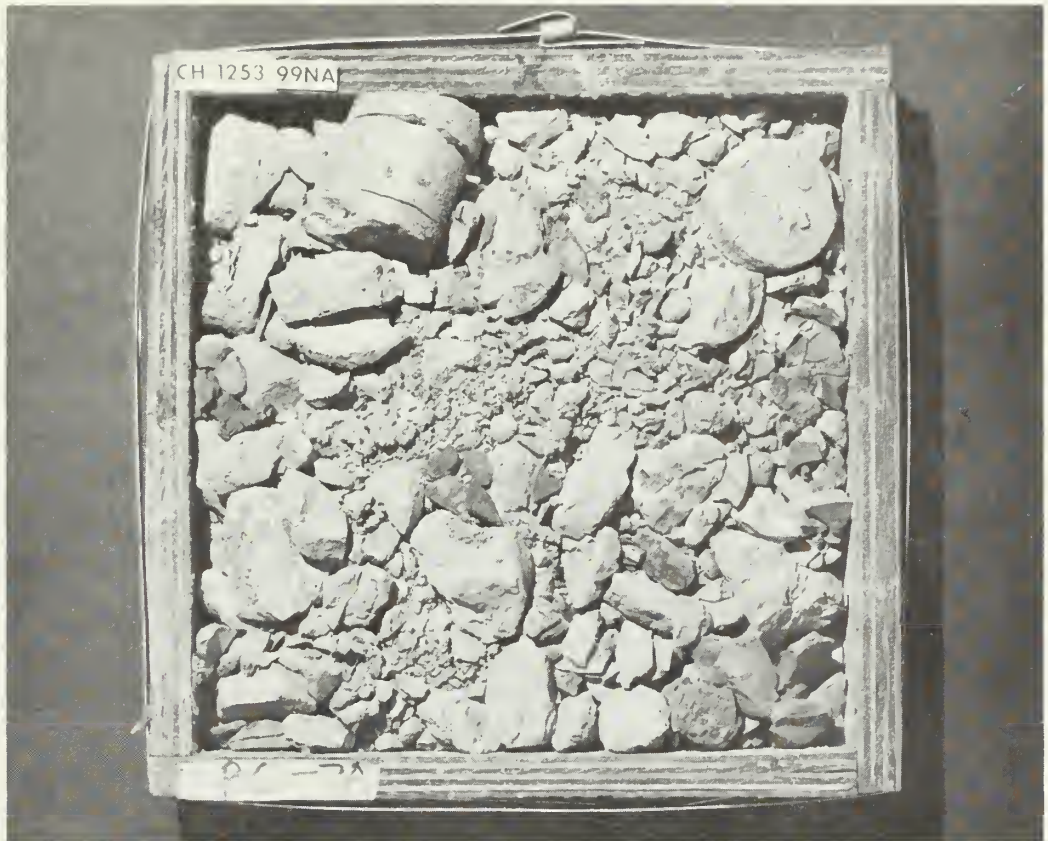


Photo 12 — Condition of composite sample PC-7A after 20 laboratory cycles.



Photograph 13



Photo 13 — — original condition of composite sample PC-7B



Photograph 14

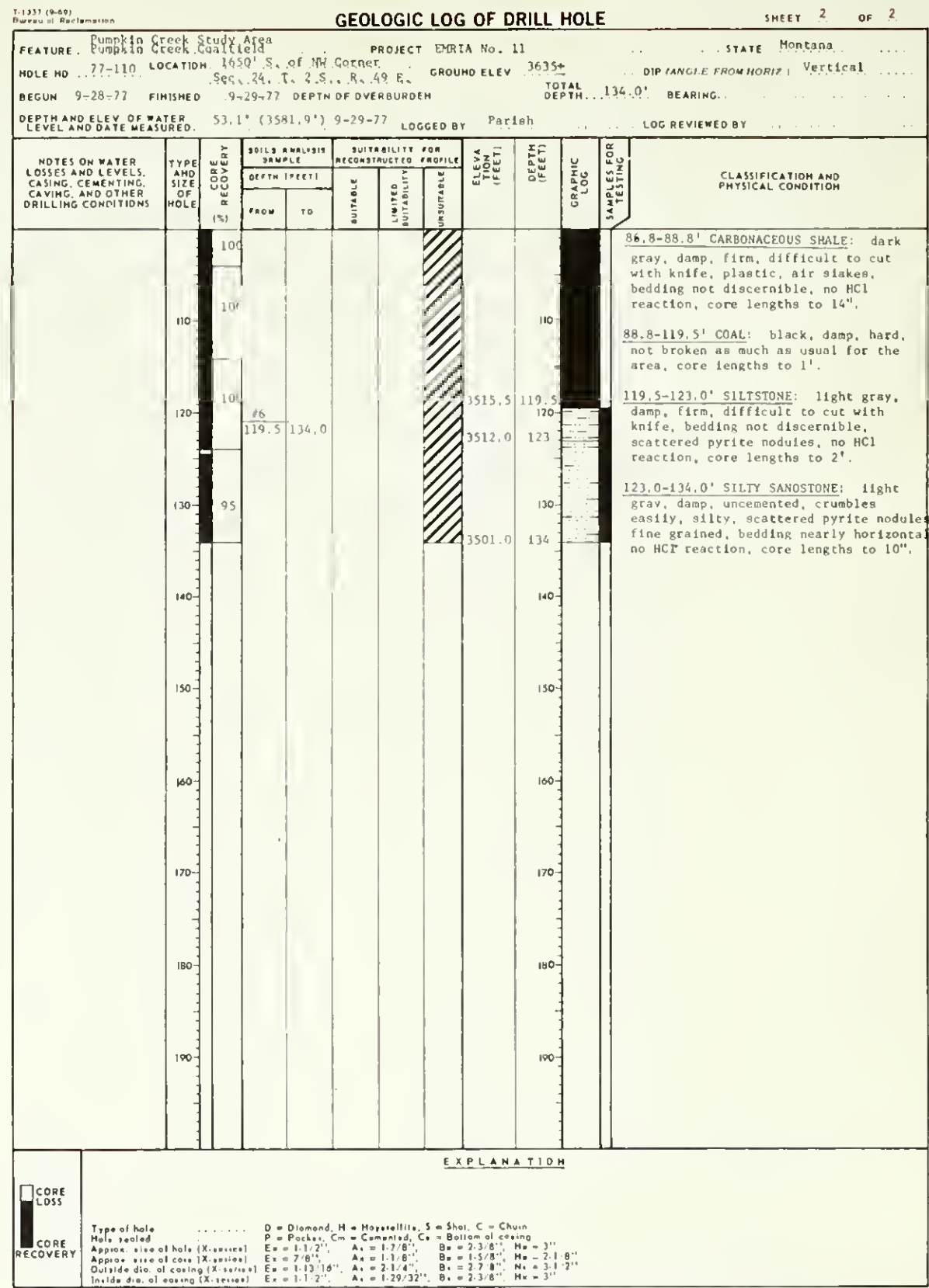
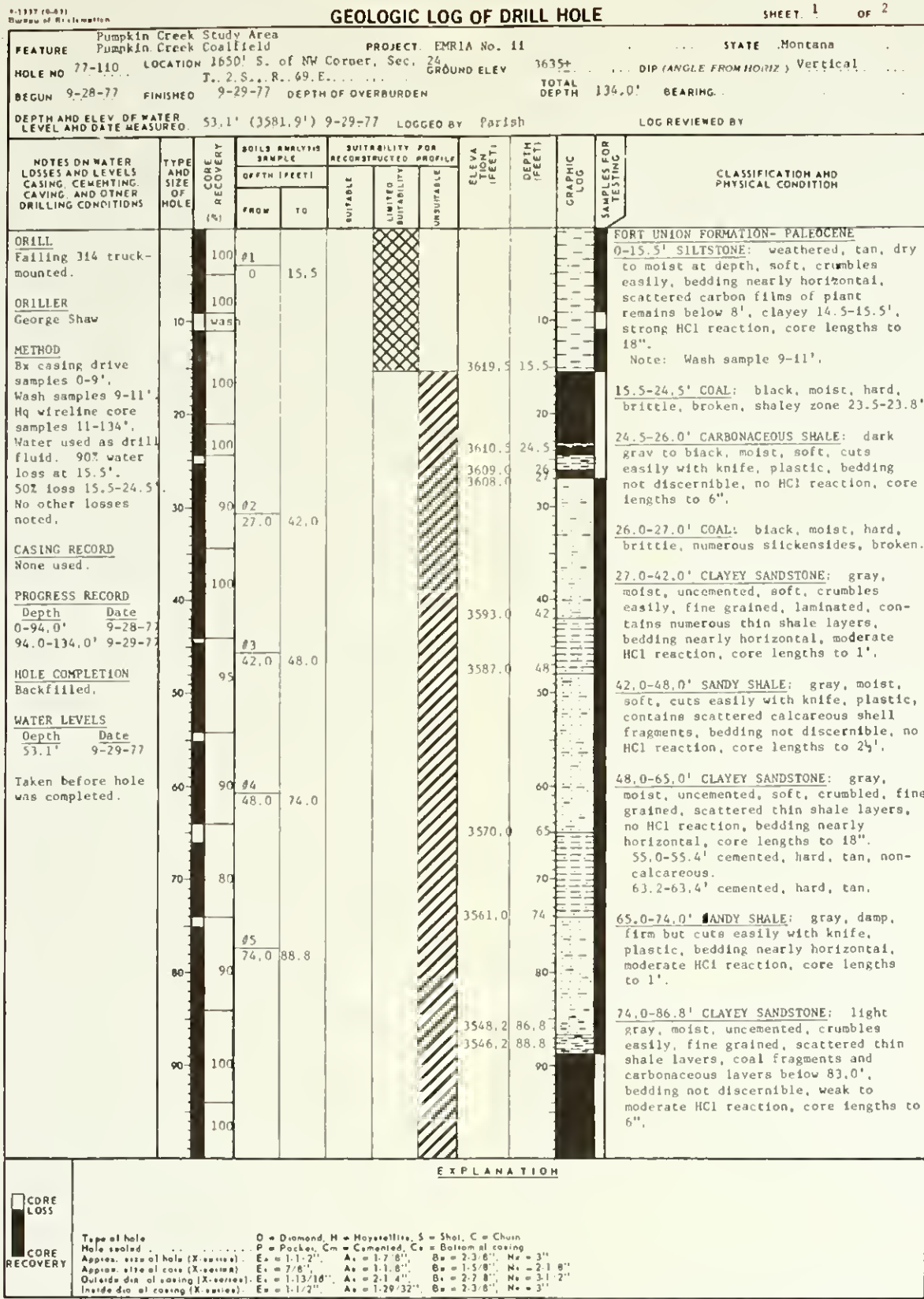


Photo 14 -- Condition of composite sample PC-7B after one year of outdoor weathering.



APPENDIX C  
COAL RESOURCES





Depth on logs in feet.  
Multiply feet by 0.3048 to obtain meters.

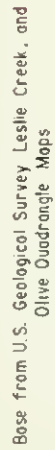
UNITED STATES  
DEPARTMENT OF THE INTERIOR  
WATER AND POWER RESOURCES SERVICE  
RESOURCE AND POTENTIAL RECLAMATION EVALUATION  
PUMPKIN CREEK STUDY AREA  
PUMPKIN CREEK COALFIELD-MONTANA

### GEOLOGIC LOG OF DH 77-110

GEOLOGY: L. PARISH	FIELD APPROVAL: _____
DRAWN: _____	TECH. APPROVAL: _____
CHECKED: _____	APPROVED: _____

BILLINGS, MONTANA      FEBRUARY 1981      1305-600-221  
SHEET 1 OF 1





CONTOUR INTERVAL 20 FEET

SCALE 1:24,000



STRUCTURE MAP ON TOP OF COAL BED A, PUMPKIN CREEK EMRIA STUDY SITE, LESLIE CREEK AND OLIVE QUADRANGLES, POWDER RIVER COUNTY, MONTANA, SHOWING THE CATEGORIES OF COAL RESOURCES LISTED ON TABLES 3 AND 4

BY  
MARGUERITE GLENN

1978

### EXPLANATION

OUTCROP OF COAL BED A OF THE TONGUE RIVER MEMBER, FORT UNION FORMATION (PALEOCENE) (LOWER SPLIT OF SAWYER)--drawn on base of coal. Triangle indicates a locality at which coal was measured. Thickness of coal is shown in feet. Approximate altitude of top of bed is shown in feet above mean sea level.

STRUCTURE CONTOUR--Drawn on top of coal bed A. Number is altitude above mean sea level. Contour interval 20 feet (6.1 meters)

APPROXIMATE NORTH EDGE OF COAL BED A--South of this line the parting separating coal bed A from the Sawyer is more than 2 feet (0.61 meters) thick

### RESOURCE AREA CONTACT

RESOURCE AREA CONTACT WHERE OVERBURDEN EXCEEDS 200 FEET (61 METERS)--For some very small areas with more than 200 feet (61 meters) of overburden resources were not separated from those of the adjoining areas with less than 200 feet (61 meters) of overburden.

AREA OF MEASURED RESOURCES--Area that is within 0.25 mile (0.40 km) of a point of observation on the coal bed

AREA OF INDICATED RESOURCES--Area that is between 0.25 mile (0.40 km) and 0.75 mile (1.21 km) of point of observation on the coal bed

AREA OF INFERRED RESOURCES--Area that is more than 0.75 mile (1.41 km) from a point of observation on the coal bed

DRILL HOLE--Number shown above  
Altitude of top of coal bed A shown in feet above mean sea level  
Holes drilled for the EMRIA study are shown as follows:

Previously drilled holes from which data (Watson, Blumner, and Wegelin, 1973, pls. 15, 17; geophysical and drillers' logs) were used are shown as follows:

US-P. Hole drilled by U.S. Geological Survey  
PC10-PC17, and PC93. Holes drilled by Northern Pacific Railroad  
and Montana Bureau of Mines and Geology

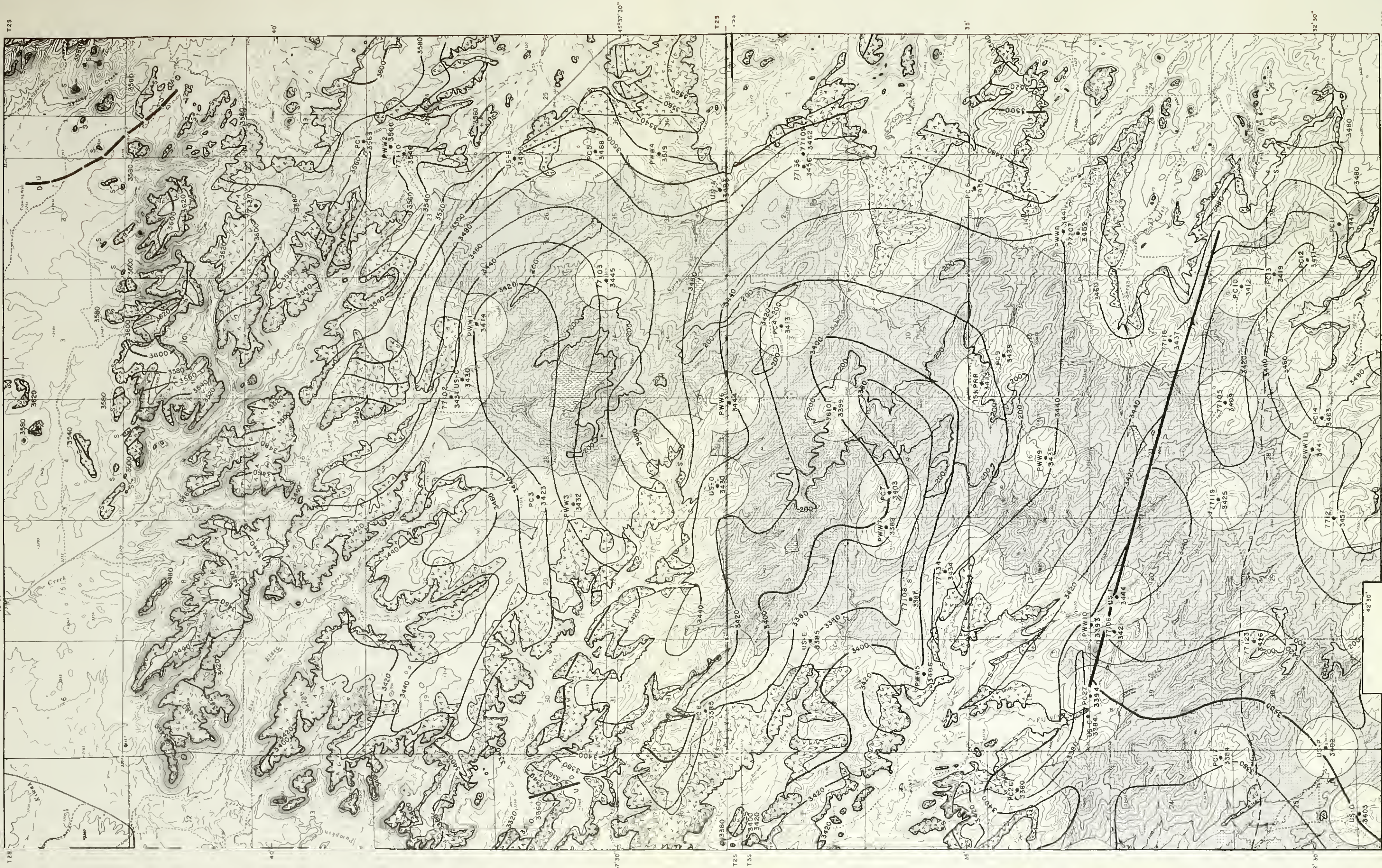
## REFERENCE

Matson, R. E., Blumer, J. W., and Wegelin, L. A., 1973, Quality and reserves of stripable coal, selected deposits, southeastern Montana: Montana Bur. Mines and Geology Bull. 91, 135 p.

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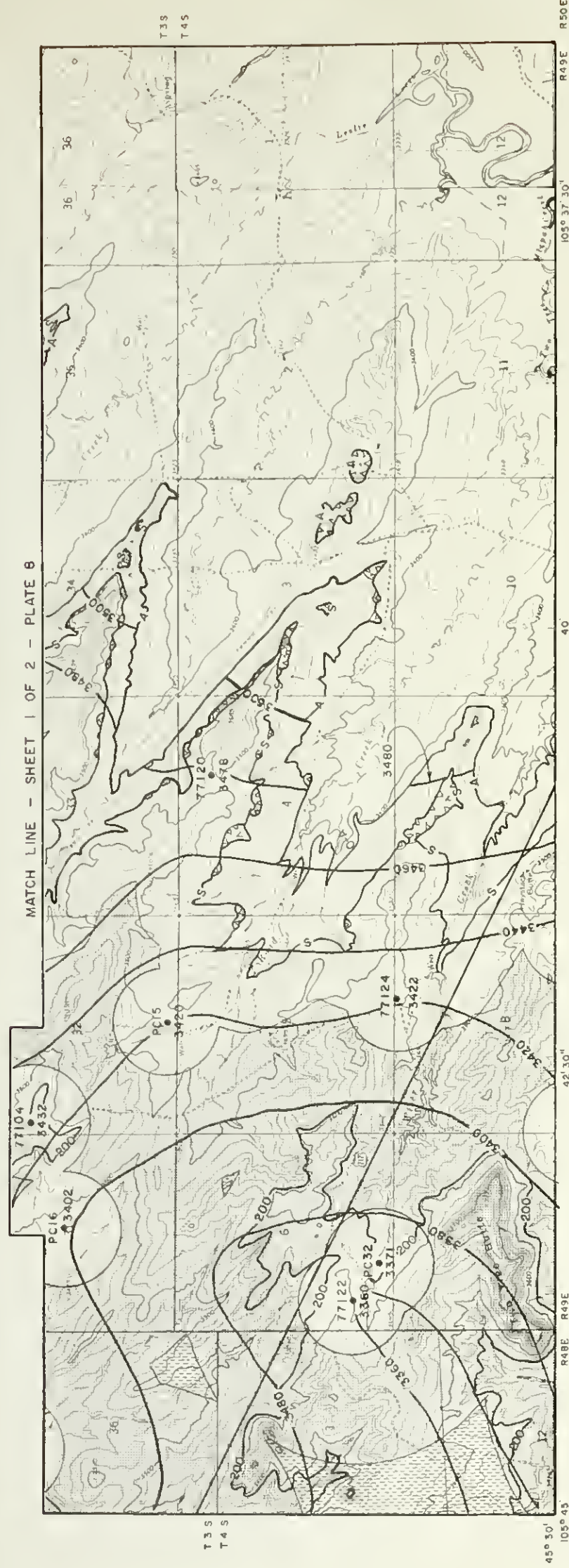
BUREAU OF RECLAMATION  
BILLINGS, MONTANA





MATCH LINE - SHEET 2 OF 2 - PLATE 8





Base from U.S. Geological Survey Box Elder Creek,  
Leslie Creek, Coalwood, and Olive Quadrangle maps

CONTOUR INTERVAL 20 FEET



SCALE 1:24,000



# STRUCTURE MAP OF THE TOP OF THE SAWYER COAL BED IN THE PUMPKIN CREEK EMRIA STUDY SITE SHOWING THE CATEGORIES OF COAL RESOURCES LISTED ON TABLES 3 AND 4

BOX ELDER CREEK, LESLIE CREEK, COALWOOD, AND OLIVE QUADRANGLES,

POWDER RIVER COUNTY, MONTANA

BY  
MARGUERITE GLENN

1978

## EXPLANATION

OUTCROP OF SAWYER COAL BED OF THE TONGUE RIVER MEMBER, FORT UNION FORMATION (PALEOCENE)--Drawn on base of coal. Dashed where inferred; dotted where concealed by alluvial deposits

OUTCROP OF COAL BED A OF THE TONGUE RIVER MEMBER, FORT UNION FORMATION (PALEOCENE) (LOWER SPLIT OF SAWYER)--Drawn on base of coal

AREA OF BURNED COAL BED--Solid line indicates approximate limit of burned coal. Heat from the burning coal bed has baked or fused the overlying rocks into a predominantly reddish resistant rock called clinker

STRUCTURE CONTOUR--Drawn on top of Sawyer coal bed or projected top of Sawyer. Number is altitude above mean sea level in feet. Contour interval 20 feet (6.1 meters)

FAULT--U, Upthrown side; D, Downthrown side

APPROXIMATE NORTH EDGE OF PARTING SEPARATING THE COAL BED A FROM THE SAWYER

RESOURCE AREA CONTACT

RESOURCE AREA CONTACT WHERE OVERBURDEN EXCEEDS 200 FEET--For some very small areas with more than 200 feet of overburden resources were not separated from those of the adjoining areas with less than 200 feet of overburden

AREA OF MEASURED RESOURCES--Area that is within 0.25 mile (0.40 km) of a point of observation on the coal bed

AREA OF INDICATED RESOURCES--Area that is between 0.25 mile (0.40 km) and 0.75 mile (1.21 km) of a point of observation on the coal bed

AREA OF INFERRED RESOURCES--Area that is more than 0.75 mile (1.21 km) from a point of observation on the coal bed

DRILL HOLE--Number shown above

Altitude of surface shown in feet above mean sea level

Holes drilled for the EMRIA study are shown as follows:

PMWL--PMWL1, Holes drilled by U.S. Geological Survey

76101, 77102--77110, Holes drilled by the U.S. Bureau of Reclamation

77118--77137, Holes drilled by Montana Bureau of Mines and Geology and U.S. Geological Survey

Previously drilled holes from which data (Matson, Blumer, and Wegelin, 1973, pls. 15, 17; geophysical and drillers' logs) were used

are shown as follows:

US-A--US-G, US-O, and US-P, Holes drilled by U.S. Geological Survey

BRJ, BR9, BR10, PC1--PC17, PC26, PC27, PC32, and PC33, Holes

drilled by Northern Pacific Railroad and Montana Bureau of Mines and Geology

Greer--El Paso 100-5 NRRR, Wolf 13, 15, 16, and 14-13 NRRR,

Abandoned holes drilled in exploration for oil and gas

ABANDONED COAL MINE

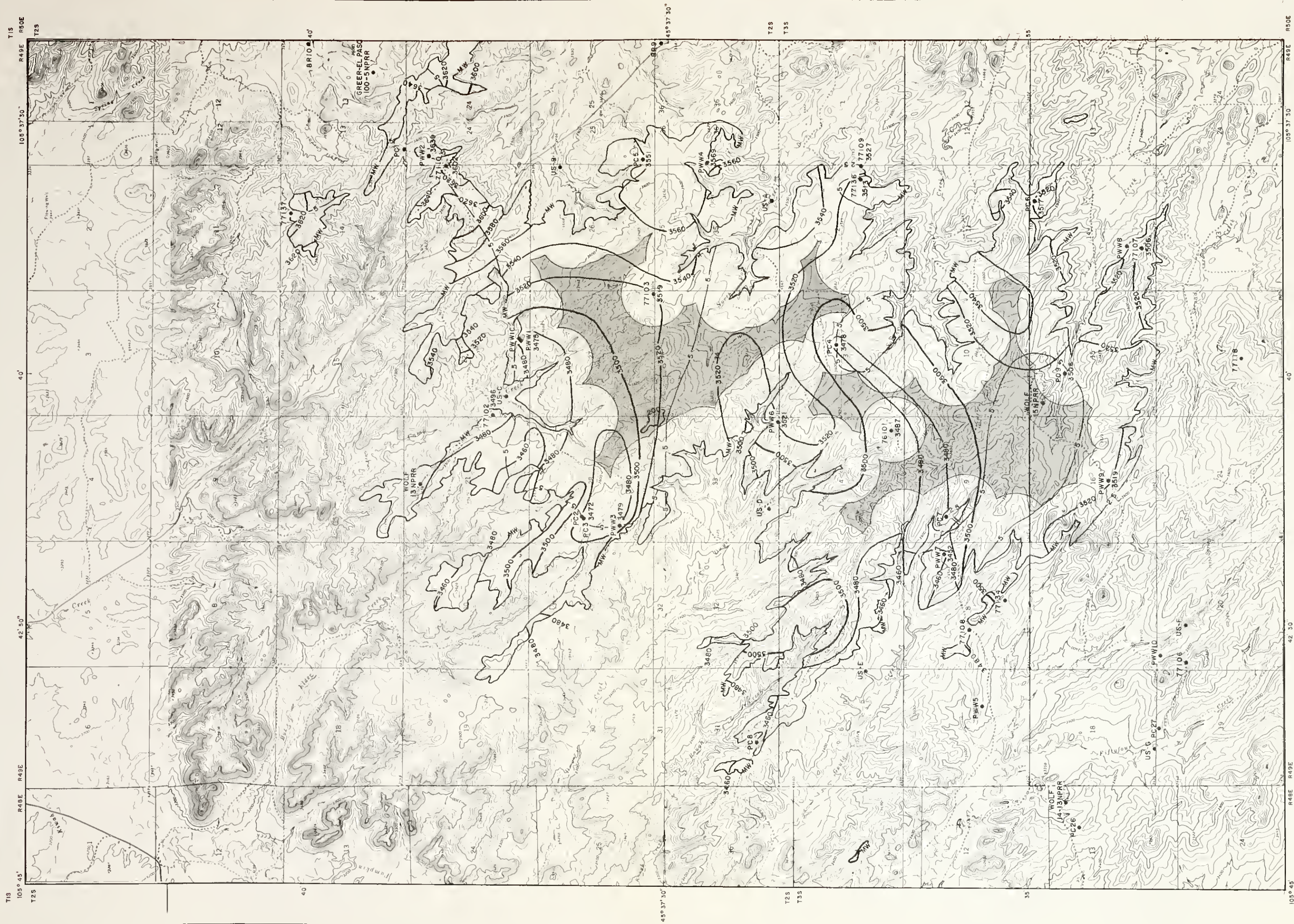
## REFERENCE

Matson, R.E., Blumer, J.W., and Wegelin, L.A., 1973, Quality and reserves of stripable coal, selected deposits, southeastern Montana: Montana Bur. Mines and Geology Bull. 91, 135 p.

REDRAFTED BY:

BUREAU OF RECLAMATION  
BILLINGS, MONTANA





Base from U.S. Geological Survey Box Elder Creek,  
Leslie Creek, Coolwood, and Olive Quadrangle maps

CONTOUR INTERVAL 20 FEET



SCALE 1:24,000



STRUCTURE MAP ON BASE OF THE MACKIN-WALKER COAL BED IN THE PUMPKIN CREEK EMRIA STUDY SITE,  
SHOWING THE CATEGORIES OF COAL RESOURCES LISTED ON TABLES 3 AND 4.

POWDER RIVER COUNTY, MONTANA

BY  
MARGUERITE GLENN  
1978

### EXPLANATION

- MW — OUTCROP OF MACKIN-WALKER COAL BED OF THE TONGUE RIVER MEMBER, FORT UNION FORMATION (PALEOCENE)—Drawn on base of coal
- 3520 — STRUCTURE CONTOUR—Drawn on base of Mackin-Walker coal bed. Contour interval 20 feet
- 3500 — RESOURCE AREA CONTACT
- 2.5 — RESOURCE AREA CONTACT WHERE MACKIN-WALKER COAL BED IS 2.5 FEET (0.76 m) THICK—No resources were calculated where coal bed is less than 2.5 feet (0.76 m) thick
- 5 — RESOURCE AREA CONTACT WHERE MACKIN-WALKER COAL BED IS 5 FEET (1.5 m) THICK

- AREA OF MEASURED RESOURCES—Area that is within 0.25 mile (0.40 km) of a point of observation on the coal bed
- AREA OF INDICATED RESOURCES—Area that is between 0.25 mile (0.40 km) and 0.75 mile (1.21 km) of a point of observation on the coal bed
- PW1 3521 DRILL HOLE—Number shown above

Altitude of base of Mackin-Walker coal bed shown in feet above mean sea level.

Holes drilled for the EMRIA study are shown as follows:

PW1—PW10, Holes drilled by U.S. Geological Survey

Bureau of Reclamation

77118, 77136, 77136, and 77137. Holes drilled by Montana Bureau of Mines and Geology and U.S. Geological Survey

Previous drilling data (Mackin-Walker data) (Mackin-Walker, Blumer, and Wegelin, 1973, p. 15; 17; Kenney and Drillers' logs) were used

are shown as follows:

US-A—US-G. Holes drilled by U.S. Geological Survey

BH9, BR10, PC1—PC8, PC26 and PC27, Holes drilled by Northern Pacific Railroad and Montana Bureau of Mines and Geology

Greenwood Mine 100-5 NFRA, Wolf 13, 15, and 14-13 NFRA, Abandoned holes drilled in exploration for oil and gas

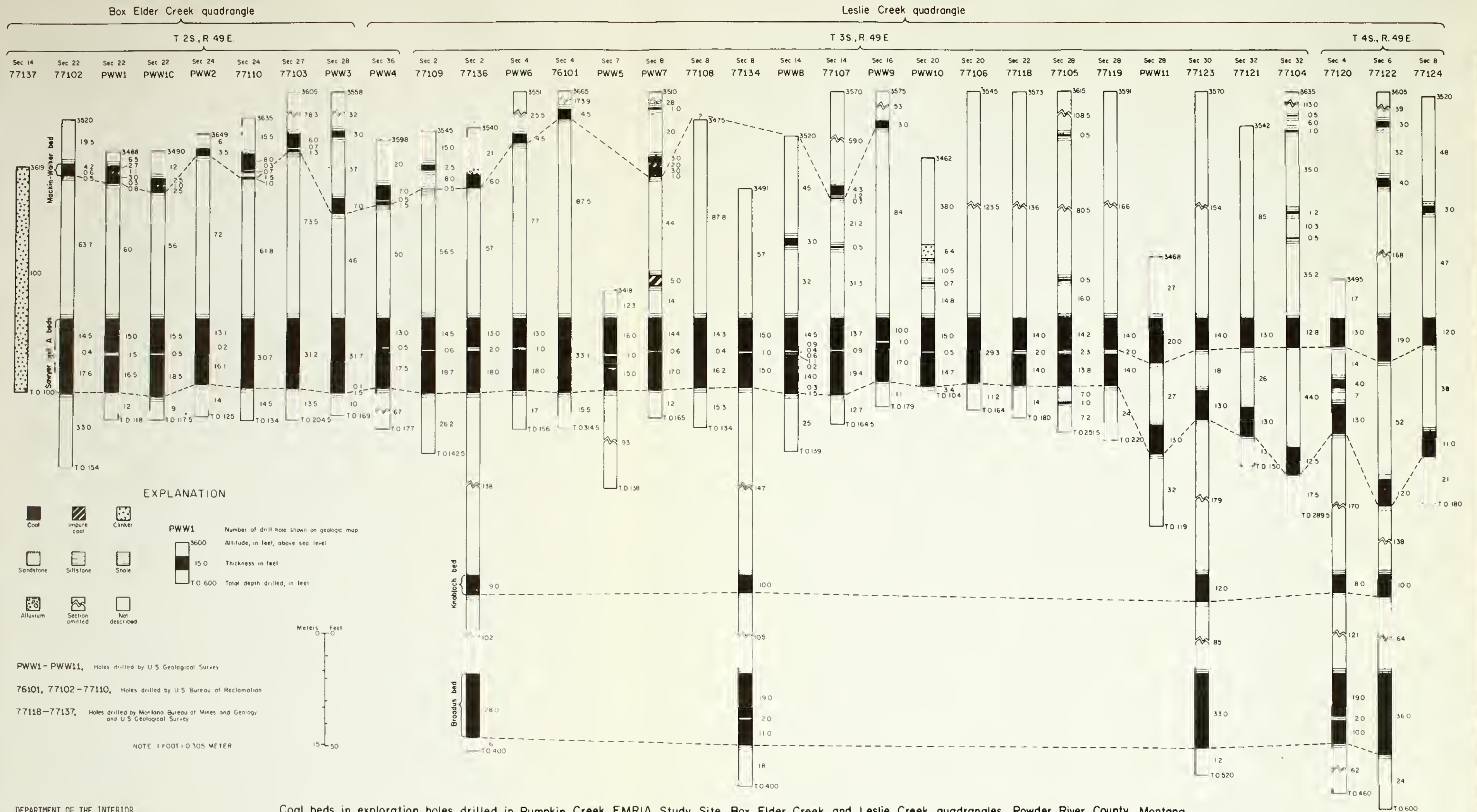
ABANDONED COAL MINE

### REFERENCE

Mackin, R.E., Blumer, J.H., and Wegelin, L.A., 1973, Quality and quantity of stripminable coal, selected deposits, southeastern Montana, Montana Bur. Mines and Geology Bull. 91, 135 p.

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BUREAU OF RECLAMATION  
BILLINGS, MONTANA





DEPARTMENT OF THE INTERIOR  
UNITED STATES GEOLOGICAL SURVEY

Coal beds in exploration holes drilled in Pumpkin Creek EMRIA Study Site, Box Elder Creek and Leslie Creek quadrangles, Powder River County, Montana  
By  
Marguerite Glenn  
1978



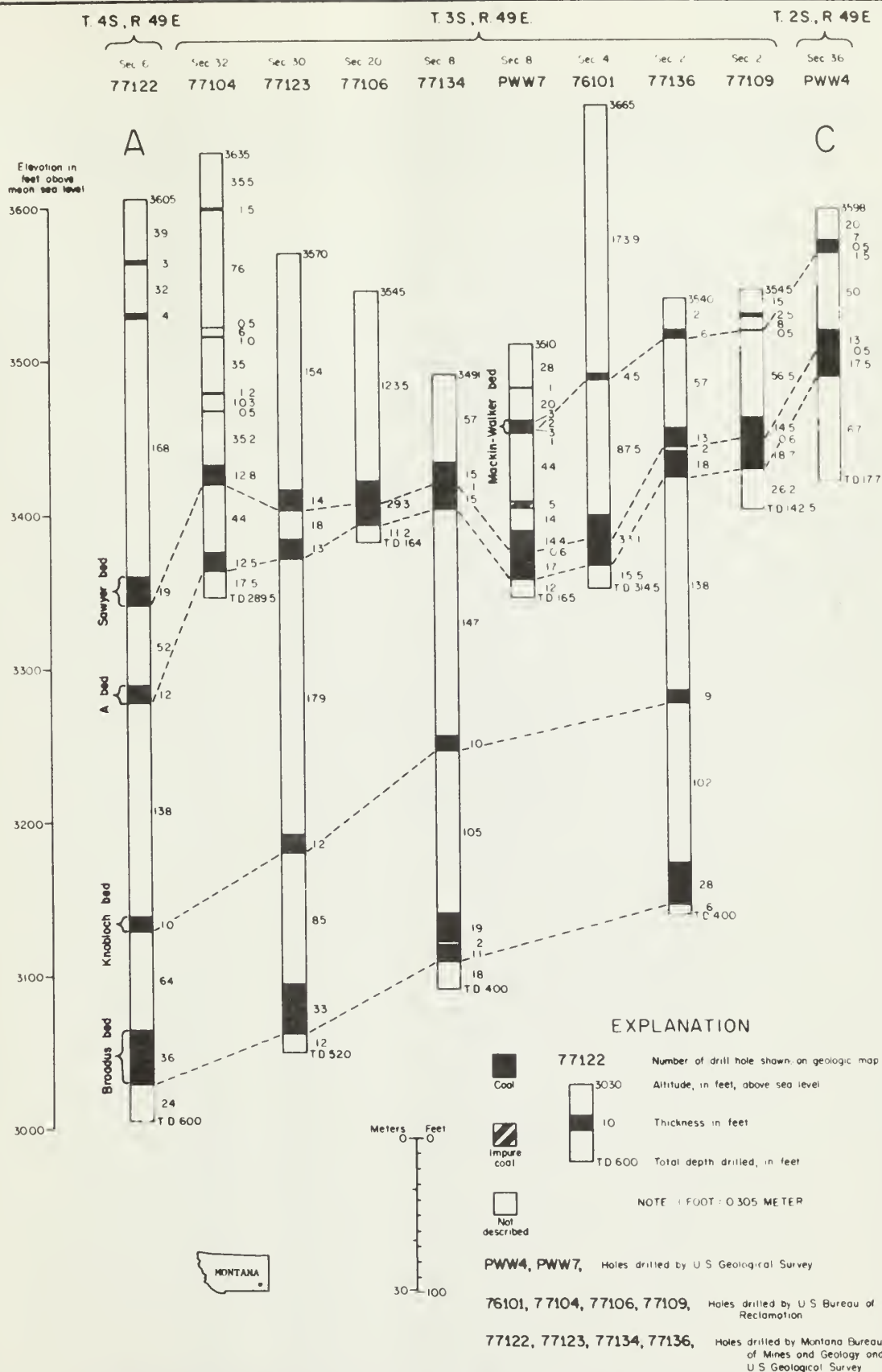




Table 2 --Surface localities, measurements, and observations of coal beds in Pumpkin Creek EMRIA study site, Powder River County, Montana

Locality number	Location			Coal bed	Coal thickness (in feet)	Quadrangle
	Section	Township	Range			
1	1	2 S.	49 E.	Knobloch	4.2+	Coalwood
2	1	2 S.	49 E.	---do---	3.5	Do.
3	1	2 S.	49 E.	---do---	3.7	Do.
4	1	2 S.	49 E.	---do---	3.3	Do.
5	1	2 S.	49 E.	---do---	3.8	Do.
6	1	2 S.	49 E.	---do---	2.0+	Do.
7	1	2 S.	49 E.	---do---	3.3	Box Elder Creek
8	1	2 S.	49 E.	---do---	3.7	Coalwood
9	1	2 S.	49 E.	---do---	3.2	Do.
10	1	2 S.	49 E.	---do---	4.5	Box Elder Creek
11	2	2 S.	49 E.	---do---	2.0	Do.
12	2	2 S.	49 E.	---do---	2.3	Coalwood
13	2	2 S.	49 E.	---do---	3.6	Box Elder Creek
14	3	2 S.	49 E.	Flowers-Goodale	3.8+	Do.
15	3	2 S.	49 E.	Knobloch	4.1	Do.
16	3	2 S.	49 E.	Flowers-Goodale	3.1	Do.
17	3	2 S.	49 E.	Knobloch	3.8	Do.
18	3	2 S.	49 E.	Flowers-Goodale	3.3	Do.
19	3	2 S.	49 E.	Knobloch	5.2+	Do.
20	3	2 S.	49 E.	---do---	4.0+	Do.
21	3	2 S.	49 E.	---do---	2.6	Do.
22	4	2 S.	49 E.	---do---	7.2	Do.
23	4	2 S.	49 E.	---do---	7.4	Do.
24	4	2 S.	49 E.	---do---	6.7	Do.
25	4	2 S.	49 E.	---do---	4.1	Do.
26	4	2 S.	49 E.	---do---	2.8	Do.
27	4	2 S.	49 E.	---do---	8.2	Do.
28	4	2 S.	49 E.	---do---	2.2	Do.
29	4	2 S.	49 E.	---do---	3.2	Do.
30	4	2 S.	49 E.	---do---	3.6	Do.
31	5	2 S.	49 E.	Flowers-Goodale	2.3	Do.
32	5	2 S.	49 E.	---do---	2.5	Do.
33	5	2 S.	49 E.	---do---	1.1	Do.
34	5	2 S.	49 E.	---do---	3.8	Do.
35	5	2 S.	49 E.	---do---	1.5	Do.
36	5	2 S.	49 E.	---do---	3.2	Do.
37	5	2 S.	49 E.	---do---	1.8	Do.
38	5	2 S.	49 E.	Local 2	1.7	Do.
39	5	2 S.	49 E.	Flowers-Goodale	3	Do.
40	5	2 S.	49 E.	---do---	2.8	Do.
41	6	2 S.	49 E.	---do---	2.0	Do.
					3.4	

Table 2 --Surface localities, measurements, and observations of coal beds in  
Pumpkin Creek EMRIA study site, Powder River County, Montana--Continued

Locality number	Location			Coal bed	Coal thickness (in feet)	Quadrangle
	Section	Township	Range			
42	6	2 S.	49 E.	Flowers-Goodale	2.0 3.8	Box Elder Creek
43	6	2 S.	49 E.	Knobloch	3.3 2.4	Do.
44	6	2 S.	48 E.	---do---	0.7	Do.
45	6	2 S.	48 E.	Flowers-Goodale	2.6	Do.
46	6	2 S.	49 E.	---do---	2.6	Do.
47	6	2 S.	49 E.	---do---	1.4	Do.
48	6	2 S.	49 E.	---do---	1.5	Do.
49	7	2 S.	49 E.	Knobloch	trace	Do.
50	7	2 S.	49 E.	---do---	1.1+	Do.
51	8	2 S.	49 E.	Flowers-Goodale	2.2	Do.
52	8	2 S.	49 E.	Knobloch	1.7+	Do.
53	8	2 S.	49 E.	---do---	2.8	Do.
54	8	2 S.	49 E.	---do---	2.3	Do.
55	8	2 S.	49 E.	Flowers-Goodale	2.7	Do.
56	8	2 S.	49 E.	---do---	3.7	Do.
57	9	2 S.	49 E.	Knobloch	7	Do.
58	9	2 S.	49 E.	---do---	7.5	Do.
59	9	2 S.	49 E.	---do---	7.1+	Do.
60	12	2 S.	49 E.	---do---	3.5	Coalwood
61	12	2 S.	49 E.	---do---	2.0	Do.
62	13	2 S.	49 E.	---do---	1.7	Do.
63	14	2 S.	49 E.	Mackin-Walker	7.2	Box Elder Creek
64	14	2 S.	49 E.	---do---	3.0+	Do.
65	17	2 S.	49 E.	Knobloch	.8	Do.
66	20	2 S.	49 E.	Mackin-Walker	3	Do.
67	22	2 S.	49 E.	---do---	5+	Do.
68	22	2 S.	49 E.	---do---	4.9	Do.
69	22	2 S.	49 E.	---do---	4.9	Do.
70	22	2 S.	49 E.	---do---	4.5	Do.
71	23	2 S.	49 E.	---do---	1.5+	Do.
72	23	2 S.	49 E.	---do---	2+	Do.
73	23	2 S.	49 E.	---do---	2.5+	Do.
74	23	2 S.	49 E.	---do---	5.1	Do.
75	24	2 S.	49 E.	---do---	7.3	Coalwood
76	24	2 S.	49 E.	---do---	4+	Box Elder Creek
77	24	2 S.	49 E.	---do---	2+	Do.
78	24	2 S.	49 E.	---do---	4.8	Do.
79	26	2 S.	49 E.	Sawyer	5.0+	Do.
80	26	2 S.	49 E.	---do---	9.5+	Do.
81	26	2 S.	49 E.	---do---	10.6+	Do.
82	26	2 S.	49 E.	Mackin-Walker	3.8	Do.
83	26	2 S.	49 E.	---do---	4+	Do.
84	26	2 S.	49 E.	---do---	5.2	Do.
85	27	2 S.	49 E.	---do---	5	Do.
86	27	2 S.	49 E.	---do---	5.2	Do.
87	27	2 S.	49 E.	Stump	3.4	Do.

Table 2 --Surface localities, measurements, and observations of coal beds in Pumpkin Creek EMRIA study site, Powder River County, Montana--Continued

Locality number	Location			Coal bed	Coal thickness (in feet)	Quadrangle
	Section	Township	Range			
88	27	2 S	49 E.	Stump	2.9	Box Elder Creek
89	27	2 S	49 E.	---do---	2.8	Do.
90	28	2 S.	49 E.	Mackin-Walker	6.2+	Do.
91	28	2 S.	49 E.	---do---	6.2+	Do.
92	28	2 S.	49 E.	---do---	4	Do.
93	28	2 S.	49 E.	---do---	3.3	Do.
94	28	2 S.	49 E.	Stump	2.7	Do.
95	30	2 S.	49 E.	Sawyer	12+	Do.
96	30	2 S.	49 E.	---do---	16	Do.
97	31	2 S.	49 E.	---do---	9.5	Leslie Creek
98	31	2 S.	49 E.	---do---	3.4	Do.
99	31	2 S.	49 E.	Mackin-Walker	2.9	Do.
100	31	2 S.	49 E.	---do---	3.7	Do.
101	32	2 S.	49 E.	---do---	2.6	Do.
102	33	2 S.	49 E.	---do---	3.0	Do.
103	33	2 S.	49 E.	---do---	2.6	Do.
104	33	2 S.	49 E.	---do---	2+	Do.
105	33	2 S.	49 E.	---do---	2.8+	Do.
106	34	2 S.	49 E.	Stump	2.0+	Do.
107	34	3 S.	49 E.	---do---	4.6	Do.
108	34	2 S.	49 E.	---do---	3.3	Do.
109	34	2 S.	49 E.	Mackin-Walker	2.7	Do.
110	35	2 S.	49 E.	---do---	9.7	Do.
111	35	2 S.	49 E.	---do---	4.1	Do.
112	35	2 S.	49 E.	---do---	1.2	Do.
113	35	2 S.	49 E.	Sawyer	5+	Do.
114	35	2 S.	49 E.	---do---	8+	Do.
115	35	3 S.	49 E.	---do---	27.5	Do.
116	36	2 S.	49 E.	Mackin-Walker	5.3	Do.
117	1	2 S.	48 E.	Flowers-Goodale	2.8	Box Elder Creek
118	1	2 S.	48 E.	---do---	2.2	Do.
119	1	2 S.	48 E.	---do---	1.6	Do.
120	1	2 S.	48 E.	Knobloch	3.0+	Do.
121	12	2 S.	48 E.	Flowers-Goodale	2.6	Do.
122	13	2 S.	48 E.	Knobloch	1.0+	Do.
123	24	2 S.	48 E.	---do---	6.2+	Do.
124	24	2 S.	48 E.	Sawyer	4.8+	Do.
125	2	3 S.	49 E.	Mackin-Walker	4	Leslie Creek
126	2	3 S.	49 E.	---do---	3.5	Do.
127	2	3 S.	49 E.	---do---	3.5	Do.
128	2	3 S.	49 E.	---do---	3.7	Do.
129	2	3 S.	49 E.	---do---	2.3	Do.
130	3	3 S.	49 E.	---do---	3.2	Do.
131	3	3 S.	49 E.	---do---	3.8	Do.
132	3	3 S.	49 E.	---do---	3.7	Do.
133	3	3 S.	49 E.	---do---	5.3	Do.
134	4	3 S.	49 E.	---do---	2.5	Do.
135	4	3 S.	49 E.	---do---	3.2	Do.
136	4	3 S.	49 E.	Stump	2.85	Do.

Table 2 --Surface localities, measurements, and observations of coal beds in  
Pumpkin Creek EMRIA study site, Powder River County, Montana--Continued

Locality number	Location			Coal bed	Coal thickness (in feet)	Quadrangle
	Section	Township	Range			
137	4	3 S.	49 E.	Stump	2.6	Leslie Creek
138	4	3 S.	49 E.	---do---	2.6	Do.
139	5	3 S.	49 E.	Mackin-Walker	2.8	Do.
140	5	3 S.	49 E.	---do---	2.5	Do.
141	5	3 S.	49 E.	---do---	2.6	Do.
142	6	3 S.	49 E.	---do---	2.8+	Do.
143	6	3 S.	49 E.	---do---	3.3	Do.
144	7	3 S.	49 E.	---do---	2.3	Do.
145	8	3 S.	49 E.	---do---	3.0	Do.
146	8	3 S.	49 E.	---do---	1.3+	Do.
147	8	3 S.	48 E.	---do---	2.6	Do.
148	8	3 S.	49 E.	---do---	2.9	Do.
149	9	3 S.	49 E.	---do---	2.8	Do.
150	9	3 S.	49 E.	---do---	2.6	Do.
151	11	3 S.	49 E.	---do---	0.6+	Do.
152	11	3 S.	49 E.	---do---	0.5+	Do.
153	13	3 S.	49 E.	Sawyer	10+	Do.
154	13	3 S.	49 E.	Mackin-Walker	3.6	Olive
155	13	3 S.	49 E.	---do---	4.1	Do.
156	13	3 S.	49 E.	---do---	3.9	Do.
157	14	3 S.	49 E.	---do---	2.8+	Leslie Creek
158	14	3 S.	49 E.	---do---	4.0	Do.
159	14	3 S.	49 E.	---do---	3.8	Do.
160	14	3 S.	49 E.	---do---	3.8	Do.
161	14	3 S.	49 E.	---do---	3.2	Do.
162	14	3 S.	49 E.	---do---	3.1	Do.
163	14	3 S.	49 E.	---do---	2.5+	Do.
164	14	3 S.	49 E.	---do---	1.2+	Do.
165	15	3 S.	49 E.	---do---	.8+	Do.
166	15	3 S.	49 E.	---do---	3+	Do.
167	15	3 S.	49 E.	---do---	3.2	Do.
168	16	3 S.	49 E.	---do---	1.2	Do.
169	21	3 S.	49 E.	---do---	trace	Do.
170	22	3 S.	49 E.	---do---	.5	Do.
171	23	3 S.	49 E.	---do---	3.5	Do.
172	28	3 S.	49 E.	Sawyer	5+	Do.
173	30	3 S.	49 E.	Stump	1.7	Do.
174	30	3 S.	49 E.	Local 4	2.3	Do.
175	31	3 S.	49 E.	Stump	1.8	Do.
176	31	3 S.	49 E.	Local 4	1.1	Do.
177	31	3 S.	49 E.	Stump	2.0	Do.
178	33	3 S.	49 E.	Sawyer	trace	Do.
179	34	3 S.	49 E.	A	4+	Do.
180	34	3 S.	49 E.	Sawyer	8+	Do.
181	34	3 S.	49 E.	---do---	9.8	Do.
182	35	3 S.	49 E.	---do---	12+	Do.
183	35	3 S.	49 E.	---do---	5.7	Do.
184	36	3 S.	49 E.	A	2+	Olive

Table 2 --Surface localities, measurements, and observations of coal beds in  
Pumpkin Creek EMRIA study site, Powder River County, Montana--Continued

Locality number	Location			Coal bed	Coal thickness (in feet)	Quadrangle
	Section	Township	Range			
185	36	3 S.	49 E.	Sawyer	9	Olive
186	36	3 S.	49 E.	---do---	7	Do.
187	1	3 S.	48 E.	Mackin-Walker	2.6	Leslie Creek
188	1	3 S.	48 E.	---do---	2.2	Do.
189	12	3 S.	48 E.	Sawyer	1.3	Do.
190	3	4 S.	49 E.	---do---	10.2+	Do.
191	5	4 S.	49 E.	Local 3	1.6	Do.
192	5	4 S.	49 E.	---do---	2.3	Do.
193	5	4 S.	49 E.	Sawyer	6.0+	Do.
194	7	4 S.	49 E.	Local 6	2.3	Do.
195	7	4 S.	49 E.	---do---	2.3	Do.
196	7	4 S.	49 E.	---do---	1.0	Do.
197	7	4 S.	49 E.	Local 5	3.0	Do.
198	7	4 S.	49 E.	---do---	2.6	Do.
199	8	4 S.	49 E.	Local 3	1.4	Do.
200	9	4 S.	49 E.	---do---	1.2	Do.
201	9	4 S.	49 E.	Sawyer	4.3+	Do.
202	9	4 S.	49 E.	Local 3	3.2+	Do.
203	1	4 S.	48 E.	Local 6	3.0	Do.
204	1	4 S.	48 E.	---do---	3.0	Do.
205	1	4 S.	48 E.	---do---	1.3	Do.
206	1	4 S.	48 E.	---do---	2.6	Do.
207	1	4 S.	48 E.	Local 5	2.9	Do.
208	1	4 S.	48 E.	Local 6	2.5	Do.
209	1	4 S.	48 E.	---do---	2.8	Do.
210	1	4 S.	48 E.	---do---	2.2	Do.



Origin

Coal has been defined as "a readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous material, formed from compaction or induration of variously altered plant remains similar to those of peaty deposits. Differences in kinds of plant materials (type), in degree of metamorphism (rank), and range of impurity (grade) are characteristics of the varieties of coal" (Schopf, 1966, p. 588). Inherent in the definition is the specification that the coal originated as a mixture of organic plant remains and inorganic mineral matter that accumulated in a manner similar to that in which modern day peat deposits are formed. The peat then underwent a long, extremely complex process called "coalification," during which diverse physical and chemical changes occurred as peat changed to coal and as the coal assumed the characteristics by which we differentiate members of the series from each other. The factors that affect the composition of coals have been summarized by Francis (1961, p. 2) as follows:

- 1) The mode of accumulation and burial of the plant debris forming the deposit.
- 2) The age of the deposits and their geographical distribution.
- 3) The structure of the coal-forming plants, particularly details of structure that affect chemical composition or resistance to decay.
- 4) The chemical composition of the coal-forming debris and its resistance to decay.
- 5) The nature and intensity of the plant-decaying agencies.
- 6) The subsequent geological history of the residual products of decay of the plant debris forming the deposits.

For extended discussion of these factors, the reader is referred to such standard works as Moore (1940), Lowry (1945, 1963), Tomkeieff (1954), and Francis (1961).

Classification

Coals can be classified in many ways (Tomkeieff, 1954, p. 9; Moore, 1940, p. 113; Francis, 1961, p. 361), but the classification by rank - that is, by degree of metamorphism in the progressive series that begins with peat and ends with graphocite (Schopf, 1966) - is the most commonly used system. Classification by types of plant materials is commonly used as a descriptive adjunct to rank classification when sufficient megascopic and microscopic

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<sup>1/</sup> Supplement to COAL RESOURCES section.

information is available, and classification by type and quantity of impurities (grade) is also frequently used when utilization of the coal is being considered. Other categorizations are possible and are commonly employed in discussion of coal resources - such factors as the weight of the coal, the thickness and areal extent of the individual coalbeds, and the thickness of overburden are generally considered.

### Rank of Coal

The position of a coal within the metamorphic series, which begins with peat and ends with graphocite, is dependent upon the temperature and pressure to which the coal has been subjected and the duration of time of subjection. Because it is, by definition, largely derived from plant material, coal is mostly composed of carbon, hydrogen, and oxygen, along with smaller quantities of nitrogen, sulfur, and other elements. The increase in rank of coal as it undergoes progressive metamorphism is indicated by changes in the proportions of the coal constituents - the higher rank coals have more carbon and less hydrogen than the lower ranks.

Two standardized forms of coal analyses - the proximate analysis and the ultimate analysis - are generally used in the world today, though sometimes only the less complicated and less expensive proximate analysis is made. The analyses are described as follows (U.S. Bur. of Mines, 1965, p. 121-122):

"The proximate analysis of coal involves the determination of four constituents: (1) water, called moisture; (2) mineral impurity, called ash, left when the coal is completely burned; (3) volatile matter, consisting of gases or vapors driven out when coal is heated to certain temperatures; and (4) fixed carbon, the solid or cokelike residue that burns at higher temperatures after volatile matter has been driven off. Ultimate analysis involves the determination of carbon and hydrogen as found in the gaseous products of combustion, the determinations of sulfur, nitrogen, and ash in the material as a whole, and the estimation of oxygen by difference."

Most coals are burned to produce heat energy so the heating value of the coal is an important property. The heating value (calorific value) is commonly expressed in British thermal units (Btu) per pound: one Btu is the amount of heat required to raise the temperature of 1 pound of water 1 degree fahrenheit (in the metric system, heating value is expressed in kilogram-calories per kilogram). Additional tests are sometimes made, particularly to determine the caking, coking, and other properties, such as tar yield, which affect classification or utilization.

Figure 3 compares, in histogram form, the heating values and moisture, volatile matter, and fixed carbon contents of coals of different ranks.

Various schemes for classifying coals by rank have been proposed and used, but the most commonly employed is that entitled "Standard specifications

Figure 3

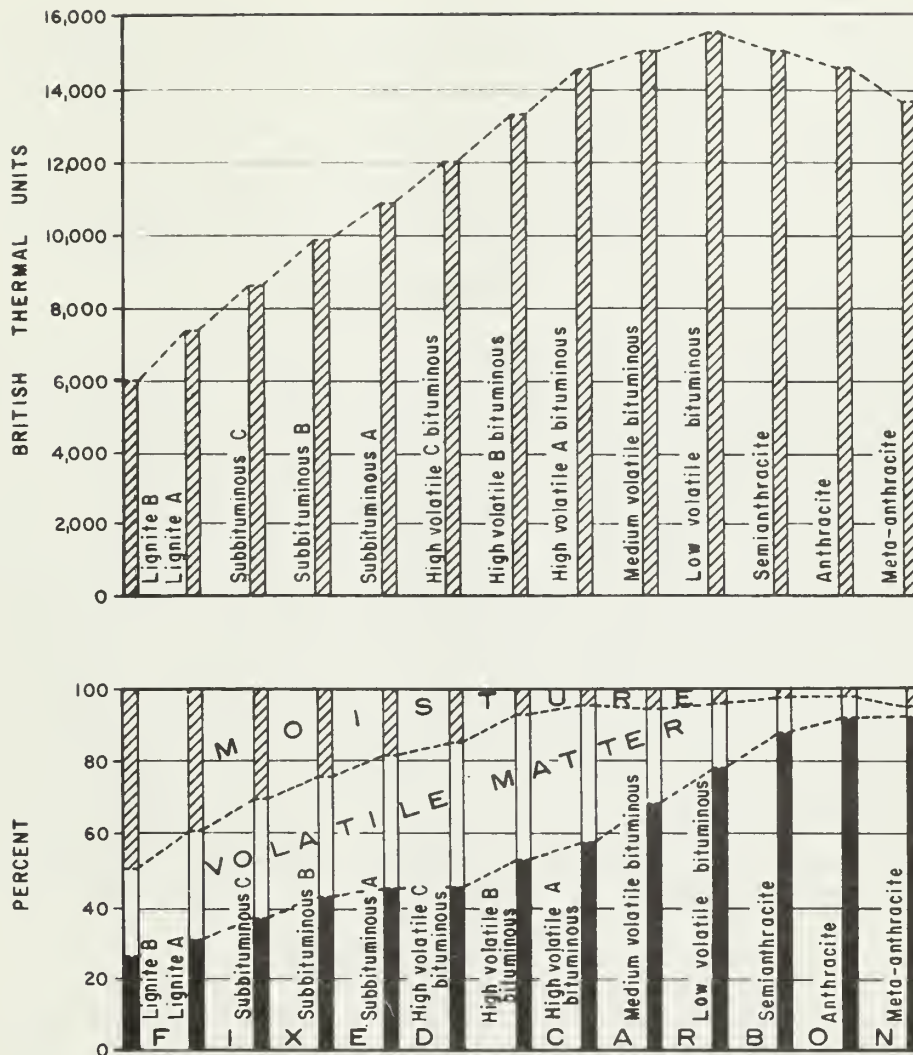


Fig. 3 -- Comparison (on moist, mineral-matter-free basis) of heat values of combustion and proximate analyses of coal of different ranks. (from Averitt, 1975, p. 17)



for classification of coals by rank," adopted by the American Society for Testing and Materials (1977). It is reproduced here as Table 5.

The ASTM classification system differentiates coals into classes and groups on the basis of mineral-matter-free fixed carbon or volatile matter and the heating value, supplemented by determination of agglomerating (caking) characteristics. As pointed out by the ASTM (1977), a standard rank determination cannot be made unless the samples were obtained in accordance with standardized sampling procedures (Snyder, 1950; Schopf, 1960). However, nonstandard samples may be used for comparative purposes through determinations designated as "apparent rank."

#### Type of Coal

Classification of coals by type - that is, according to the types of plant materials present - takes many forms, such as the "rational analysis" of Francis (1961) or the semicommercial "type" classification commonly used in the coalfields of the eastern United States (U.S. Bureau of Mines, 1965, p. 123). However, most of the type classifications are based on the same, or similar, gross distinctions in plant material as those used by Tomkeieff (1954, Table 11 and p. 9), who divided the coal into three series: humic coals, humic-sapropelic coals, and sapropelic coals, based upon the nature of the original plant materials. The humic coals are largely composed of the remains of the woody parts of plants; and the sapropelic coals are largely composed of the more resistant waxy, fatty, and resinous parts of plants, such as cell walls, spore coatings, pollen, resin particles, and coals composed mainly of algal material. Most coals fall into the humic series, with some coals being a mixture of humic and sapropelic elements and, therefore, falling into the humic-sapropelic series. The sapropelic series is quantitatively insignificant and, when found, is commonly regarded as an organic curiosity. In common with most of the U.S. coals, those from Pumpkin Creek fall largely in the humic series.

#### Grade of Coal

Classification of coal by grade, or quality, is based largely on the content of ash, sulfur, and other constituents that adversely affect utilization. Most detailed coal resource evaluations of the past do not categorize known coal resources by grade, but coals of the United States have been classified by sulfur content in a gross way (DeCarlo and other, 1966).

According to Fieldner and others (1942), ash content of 642 U.S. coal samples ranges from 2.5 to 32.6 percent, averaging 8.9 percent, and sulfur contents range from 0.2 to 7.7 percent, averaging 1.9 percent.

The ash content of the 17 samples from the Sawyer Coalbed, on an as-received basis, ranges from 4.4 to 14.2 percent, averaging 6.8 percent; sulfur content of those samples ranges from 0.2 to 1.7 percent, averaging 0.4 percent.

Seventeen samples listed on Tables 6 and 7 show an apparent rank of lignite A. Because of the lack of definitive information about the distribution

of coals of various groups in the Pumpkin Creek coal, it is considered to be all lignite A in rank in the area of the study.

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Table 5 --Classification of coals by rank<sup>1</sup>

[American Society for Testing and Materials Standard D388-77; 1 Btu equals 0.252 kilogram-calories. Leaders (—) indicate category is not used in rank determination of group]

Class	Group	Fixed Carbon Limits, percent (Dry, Mineral-Matter-Free Basis)		Volatile Matter Limits, percent (Dry, Mineral-Matter-Free Basis)		Calorific Value Limits, Btu per pound (Moist, Mineral-Matter-Free Basis)		Agglomerating Character
		Equal or Greater Than	Less Than	Greater Than	Equal or Less Than	Equal or Greater Than	Less Than	
I. Anthracite	1. Meta-anthracite	98	...	...	2	...	...	nonagglomerating
	2. Anthracite	92	98	2	8	...	...	
	3. Semianthracite <sup>3</sup>	86	92	8	14	...	...	
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	...	...	Commonly agglomerating <sup>3</sup>
	2. Medium volatile bituminous coal	69	78	22	31	...	...	
	3. High volatile A bituminous coal	...	69	31	...	14 000 <sup>4</sup>	...	
	4. High volatile B bituminous coal	...	...	...	...	13 000 <sup>4</sup>	14 000	
	5. High volatile C bituminous coal	...	...	...	...	11 500	13 000	
III. Subbituminous	1. Subbituminous A coal	...	...	...	...	10 500	11 500	agglomerating
	2. Subbituminous B coal	...	...	...	...	9 500	10 500	
	3. Subbituminous C coal	...	...	...	...	8 300	9 500	
IV. Lignite	1. Lignite A	...	...	...	...	6 300	8 300	nonagglomerating
	2. Lignite B	...	...	...	...	...	6 300	

<sup>1</sup>This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 13,500 moist, mineral-matter-free British thermal units per pound.

<sup>2</sup>Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

<sup>3</sup>If agglomerating, classify in low-volatile group of the bituminous class.

<sup>4</sup>Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.

<sup>5</sup>It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in high volatile C bituminous group.

Table 6 --Hole number, USGS sample number, location, depth interval, and description of 18 lignite and shale samples from the Tongue River Member of the Fort Union Formation, Pumpkin Creek EMRIA study site, Powder River County, Montana

Hole number	USGS sample number	Location	Depth interval feet and (meters)	Description
P1W2	D187017	S4N4W4E4 sec. 24, T. 2 S., R. 49 E.	82.8- 96.0 (25.2- 29.9)	Lignite, Sawyer bed.
P1W2	D187018	-----do-----	98.0-112.2 (29.9- 34.2)	Lignite with minor pyrite, Sawyer bed.
P1W3	D187019	S4N4W4E4 sec. 28, T. 2 S., R. 49 E.	125.9-130.0 (38.4- 39.6)	Lignite, Sawyer bed.
P1W3	D187020	-----do-----	130.0-139.6 (39.6- 42.6)	Do.
P1W3	D187021	-----do-----	139.6-149.7 (42.6- 45.6)	Do.
P1W3	D187022	-----do-----	149.7-159.5 (45.6- 48.6)	Do.
P1W8	D187023	NE4N4W4SE4 sec. 14, T. 3 S., R. 49 E.	80.2- 94.7 (24.4- 28.9)	Do.
P1W8	D187024	-----do-----	94.7- 97.9 (28.9- 29.8)	Shale, with shaly lignite.
P1W8	D187025	-----do-----	97.9-111.9 (29.8- 34.1)	Lignite with minor pyrite, Sawyer bed.
P1W8	D187026	-----do-----	112.2-113.7 (34.2- 34.7)	Lignite, Sawyer bed.
P1W10	D187014	N4N4W4E4 sec. 20, T. 3 S., R. 49 E.	54.9- 55.6 (16.7- 16.9)	Lignite, unnamed bed.
P1W10	D187015	-----do-----	70.4- 84.8 (21.5- 25.8)	Lignite, Sawyer bed.
P1W10	D187016	N4N4W4E4 sec. 20, T. 3 S., R. 49 E.	85.3-100.6 (26.0- 30.7)	Do.
76101	D189026	NW4SE4SE4 sec. 4, T. 3 S., R. 49 E.	173.9-179.1 (53.0- 54.6)	Lignite, Mackin-Walker bed.
76101	D189027	-----do-----	266.0-271.0 (81.1- 82.6)	Lignite, Sawyer bed.
76101	D189028	-----do-----	271.0-281.1 (82.6- 85.7)	Do.
76101	D189029	-----do-----	281.1-291.0 (85.7- 88.7)	Do.
76101	D189030	-----do-----	291.0-299.0 (88.7- 91.1)	Do.

Table 7 -- Proximate and ultimate analyses, heat of combustion, forms of sulfur, free-swelling index, and ash-fusion temperature determinations for 17 lignite and shale samples from the Tongue River Member of the Fort Union Formation, Pumpkin Creek ENRIA study site, Powder River County, Montana

[All analyses except Kcal/kg, Btu/lb, free swelling index, and ash-fusion temperatures in percent. For each sample number, the analyses are reported three ways; first, as received, second, moisture free, and third, moisture and ash free. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa. °C = (°F-32) 5/9; Kcal/kg = 0.556 (Btu/lb)]

Hole number	Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
PWW2	D187017	36.4	26.6	30.1	6.9	6.9	41.0	0.6	44.3	0.4	3,840	6,910
		---	41.8	47.3	10.8	4.5	64.5	.9	18.8	.6	6,040	10,860
		---	46.9	53.1	---	5.0	72.3	1.1	21.1	.7	6,770	12,180
	D187018	37.7	26.1	30.1	6.1	7.0	40.8	.7	45.0	.5	3,850	6,930
		---	41.9	48.3	9.8	4.5	65.5	1.1	18.4	.8	6,180	11,140
		---	46.4	53.6	---	5.0	72.6	1.2	20.4	.9	6,850	12,350
PWW3	D187019	36.2	26.7	31.8	5.3	6.8	42.1	.7	44.7	.3	3,950	7,100
		---	41.8	49.8	8.3	4.4	66.0	1.1	19.6	.5	6,180	11,130
		---	45.6	54.4	---	4.7	72.0	1.2	21.4	.5	6,740	12,150
	D187020	37.3	25.9	32.2	4.6	6.9	41.6	.6	46.2	.2	3,910	7,030
		---	41.3	51.4	7.3	4.4	66.3	1.0	20.8	.3	6,230	11,220
		---	44.6	55.4	---	4.7	71.6	1.0	22.5	.3	6,720	12,110
	D187021	34.9	27.5	31.2	6.4	6.8	42.2	.6	43.8	.2	3,970	7,150
		---	42.2	47.9	9.8	4.5	64.8	.9	19.6	.3	6,100	10,980
		---	46.8	53.2	---	5.0	71.9	1.0	21.8	.3	6,770	12,180
	D187022	35.3	27.4	29.4	7.9	6.8	41.2	.7	42.8	.6	3,900	7,010
		---	42.3	45.4	12.2	4.4	63.7	1.1	17.7	.9	6,020	10,840
		---	48.2	51.8	---	5.1	72.5	1.2	20.1	1.1	6,860	12,350
PWW6	D187023	38.4	26.4	30.1	5.1	7.0	40.6	.6	46.4	.2	3,810	6,850
		---	42.9	48.9	8.3	4.4	65.9	1.0	19.9	.3	6,180	11,120
		---	46.7	53.3	---	4.8	71.9	1.1	21.7	.4	6,740	12,120
	D187024	20.8	13.6	9.3	56.3	3.8	14.9	.3	24.1	.6	1,290	2,310
		---	17.2	11.7	71.1	1.9	18.8	.4	7.1	.8	1,620	2,920
		---	59.4	40.6	---	6.5	65.1	1.3	24.5	2.6	5,610	10,100
	D187025	37.5	26.0	30.3	6.2	7.0	40.5	.7	45.4	.4	3,820	6,880
		---	41.6	48.5	9.9	4.5	64.8	1.1	19.3	.6	6,120	11,000
		---	46.2	53.8	---	5.0	71.9	1.2	21.4	.7	6,790	12,200
	D187026	36.2	25.3	27.9	10.6	6.8	37.9	.6	42.4	1.7	3,660	6,600
		---	39.7	43.7	16.6	4.4	59.4	.9	16.0	2.7	5,740	10,340
		---	47.6	52.4	---	5.2	71.2	1.1	19.2	3.2	6,890	12,400
PWW10	D187015	35.8	26.7	31.9	5.6	6.8	42.0	.7	44.6	.3	3,930	7,070
		---	41.6	49.7	8.7	4.4	65.4	1.1	19.9	.5	6,120	11,010
		---	45.6	54.4	---	4.8	71.7	1.2	21.8	.5	6,700	12,050
	D187016	34.8	27.5	30.8	6.9	6.7	42.0	.7	43.2	.4	3,950	7,110
		---	42.2	47.2	10.6	4.3	64.4	1.1	18.8	.6	6,060	10,920
		---	47.2	52.8	---	4.9	72.0	1.2	21.0	.7	6,780	12,210
	D189026	35.2	29.3	28.6	6.9	6.9	42.2	.7	42.4	1.0	4,010	7,220
		---	45.2	44.1	10.6	4.6	65.1	1.1	17.1	1.5	6,190	11,150
		---	50.6	49.4	---	5.2	72.9	1.2	19.2	1.7	6,930	12,480
	D189027	34.8	27.4	31.0	6.8	6.7	42.9	.7	42.4	.3	4,030	7,260
		---	42.0	47.5	10.4	4.3	65.8	1.1	17.6	.5	6,190	11,140
		---	46.9	53.1	---	4.9	73.5	1.2	19.6	.5	6,910	12,440
76101	D189028	35.4	26.9	33.3	4.4	6.7	43.4	.7	44.6	.2	4,030	7,250
		---	41.6	51.5	6.8	4.3	67.2	1.1	20.3	.3	6,230	11,220
		---	44.7	55.3	---	4.6	72.1	1.2	21.8	.3	6,690	12,040
	D189029	30.3	32.3	31.6	5.8	6.8	42.4	.7	44.1	.2	3,990	7,180
		---	46.3	45.3	8.3	4.9	60.8	1.0	24.6	.3	5,720	10,290
		---	50.5	49.5	---	5.4	66.4	1.1	26.9	.3	6,240	11,230
	D189030	34.4	23.9	27.5	14.2	6.4	36.9	.6	41.4	.5	3,480	6,260
		---	36.4	41.9	21.6	3.9	56.3	.9	16.5	.8	5,300	9,540
		---	46.5	53.5	---	5.0	71.8	1.2	21.1	1.0	6,770	12,180

Table 7 --Proximate and ultimate analyses, heat of combustion, forms of sulfur, free-swelling index, and ash-fusion temperature determinations for 17 lignite and shale samples from the Tongue River Member of the Fort Union Formation, Pumpkin Creek ERIA study site, Powder River County, Montana--Continued

Hole number	Sample number	Air-dried loss	Forms of sulfur			Ash-fusion temperature, C°			
			Sulfate	Pyritic	Organic	Free swelling	Initial deformation	Softening	Fluid
PWW2	D187017	28.0	0.01	0.06	0.32	0.0	1,175	1,230	1,285
		---	.02	.09	.50				
		---	.02	.11	.56				
	D187018	28.7	.01	.07	.40	.0	1,155	1,215	1,265
		---	.02	.11	.64				
		---	.02	.12	.71				
	D187019	27.4	.01	.08	.22	.0	1,165	1,230	1,290
		---	.02	.13	.34				
		---	.02	.14	.38				
PWW3	D187020	28.3	.01	.06	.10	.0	1,215	1,270	1,325
		---	.02	.10	.16				
		---	.02	.10	.17				
	D187021	27.0	.01	.07	.10	.0	1,205	1,265	1,320
		---	.02	.11	.15				
		---	.02	.12	.17				
	D187022	26.3	.01	.39	.24	.0	1,120	1,180	1,235
		---	.02	.60	.37				
		---	.02	.69	.42				
	D187023	29.7	.01	.13	.05	.0	1,125	1,180	1,235
		---	.02	.21	.08				
		---	.02	.23	.09				
PWW8	D187024	17.7	.01	.33	.26	.0	1,435	1,485	1,540
		---	.01	.42	.33				
		---	.04	1.44	1.14				
	D187025	28.5	.01	.14	.21	.0	1,155	1,215	1,275
		---	.02	.22	.34				
		---	.02	.25	.37				
	D187026	29.6	.01	.53	1.16	.0	1,075	1,130	1,180
		---	.02	.83	1.82				
		---	.02	1.00	2.18				
PWW10	D187015	27.6	.01	.15	.17	.0	1,150	1,215	1,265
		---	.02	.23	.26				
		---	.02	.26	.29				
	D187016	26.4	.01	.18	.26	.0	1,180	1,230	1,295
		---	.02	.28	.40				
		---	.02	.31	.45				
	D189026	16.3	.01	.25	.74	.0	1,125	1,180	1,235
		---	.02	.39	1.14				
		---	.02	.43	1.28				
	D189027	16.9	.00	.17	.17	.0	1,150	1,205	1,265
		---	.00	.26	.26				
		---	.00	.29	.29				
76101	D189028	14.9	.01	.13	.05	.0	1,205	1,265	1,320
		---	.02	.20	.08				
		---	.02	.22	.08				
	D189029	19.8	.01	.10	.09	.0	1,180	1,240	1,290
		---	.01	.14	.13				
		---	.02	.16	.14				
	D189030	20.1	.01	.14	.38	.0	1,205	1,265	1,315
		---	.02	.21	.58				
		---	.02	.27	.74				

# Chemical Analyses of Lignite and Lignitic Shale

By

Joseph R. Hatch and Ronald H. Affolter<sup>2/</sup>

## Introduction

Seventeen lignite and one lignitic shale sample were collected from cores from five holes in the Tongue River Member of the Fort Union Formation in the Pumpkin Creek EMRIA Study Site by the U.S. Geological Survey (Fig. 1). Four of the holes, PWW2, PWW3, PWW8, and PWW10, were drilled by the U.S. Geological Survey; hole 76-101 was cored by the Water and Power Resources Service. The samples are briefly described in Table 6. Fifteen of the samples are from the Sawyer Coalbed (the principal bed of interest in this area), one (D189026) is from the Mackin-Walker Coalbed; 87 feet (26.5 m) above the Sawyer bed, and one (D187015) is from an unnamed bed 15 feet (4.5 m) above the Sawyer bed. Two samples were collected from the Sawyer bed in holes PWW2 and PWW10; four samples of the Sawyer bed were collected in holes PWW3 and 76-101. In hole PWW8, the Sawyer bed contains two partings one at a depth between 94.7 and 97.9 feet (28.9 to 29.8 m), the second at a depth between 111.9 and 112.2 feet (34.1 to 34.2 m). One sample was collected from the interval above the upper parting (D187023), one between the two partings sampled separately (D187024); the lower parting was not.

## Analytical Results

### Acknowledgements and Summary of Analytical Tables

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Proximate and ultimate analyses, heat of combustion, air-dried-loss, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations on these samples (Table 7) were provided by the U.S. Bureau of Mines, Pittsburgh, Pa. Analyses for 32 major and minor oxides and trace elements in the laboratory ash (Table 8) and analyses of nine trace elements in whole coal and shale (Table 9) were provided by the U.S. Geological Survey, Denver, Colo. Analytical procedures used by the U.S. Geological Survey are described in Swanson and Huffman (1976). Table 10 contains the data listed in Table 8 converted to a whole-coal basis and the whole-coal

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<sup>2/</sup> Supplement to COAL RESOURCES section

analyses listed in Table 9. Twenty-four additional elements were looked for but not found in amounts greater than their lower limits of detection (Table 11). Unweighted statistical summaries of the analytical data on the Sawyer bed in Tables 7, 8 and 10 are listed in Tables 12, 13 and 14, respectively. Data summaries for other Powder River region coal samples are listed for comparison.

To be consistent with the precision of the semiquantitative emission spectrographic technique, arithmetic and geometric means of elements determined by this method are reported as the midpoint of the enclosing six-step bracket. (See headnote of Table 8, or Swanson and Huffman, 1976, p. 67, for an explanation of six-step brackets).

#### Statistical Terms Used in Summary Tables

In this report the geometric mean (GM) is used as the estimate of the most probable concentration (mode); the geometric mean is calculated by taking the logarithm of each analytical value, summing the logarithms, dividing the sum by the total number of values, and obtaining the antilogarithm of the result. The measure of scatter about the mode used here is the geometric deviation (GD), which is the antilog of the standard deviation of the logarithms of the analytical values. These statistics are used because the quantities of trace elements in natural materials commonly exhibit positively skewed frequency distributions; such distributions are normalized by analyzing and summarizing trace-element data on a logarithmic basis.

If the frequency distributions are lognormal, the geometric mean is the best estimate of the mode, and the estimated range of the central two-thirds of the observed distribution has a lower limit equal to  $GM/GD$  and an upper limit equal to  $GM \cdot GD$ . The estimated range of the central 95 percent of the observed distribution has a lower limit equal to  $GM/(GD)^2$  and an upper limit equal to  $GM \cdot (GD)^2$  (Connor and others, 1976).

Although the geometric mean is, in general, an adequate estimate of the most common analytical value, it is, nevertheless, a biased estimate of the arithmetic mean. In the summary tables, the estimates of the arithmetic means are Sichel's  $t$  statistic (Miesch, 1967).

A common problem in statistical summaries of trace element data arises when the element content in one or more of the samples is below the limit of analytical detection. This results in a censored distribution. Procedures developed by Cohen (1959) were used to compute unbiased estimates of the geometric mean, geometric deviation, and arithmetic mean where the data are censored.

#### Discussion of the Analyses

The analyses of the Sawyer bed on an as-received basis (Table 7) show that ash content ranges from 4.6 to 14.2 percent, averaging 6.8 percent, sulfur content ranges from 0.2 to 1.7 percent, averaging 0.4 percent, and heat of combustion ranges from 3,480 to 4,030 Kcal/kg (6,260 to

Table 8 --Major and minor oxide and trace element composition of the laboratory ash of 18 lignite and shale samples from the Tongue River Member of the Fort Union Formation, Pumpkin Creek ENRIA study site, Powder River County, Montana

[Values in percent or parts per million. Lignite ashed at 525°C. L means less than the value shown; N, not detected; B, not determined; S after element title indicates determinations by semiquantitative emission spectrography. The spectrographic results are to be identified with geometric brackets, 0.1, 0.15, 0.2, 0.3, 0.5, 0.7, 1.0, etc. Precision of the spectrographic data is plus-or-minus one bracket at 68 percent or plus-or-minus two brackets at 95 percent confidence level]

Hole number	Sample number	Ash (percent)	SiO <sub>2</sub> (percent)	Al <sub>2</sub> O <sub>3</sub> (percent)	CaO (percent)	MgO (percent)	Na <sub>2</sub> O (percent)	K <sub>2</sub> O (percent)	Fe <sub>2</sub> O <sub>3</sub> (percent)	TiO <sub>2</sub> (percent)	ZnO (percent)	Sample number
PW2	D187017	10.5	29	11	26	4.35	4.63	0.78	5.5	1.2	1.0L	D187017
	D187018	9.1	27	13	25	5.08	5.20	.30	6.5	.72	1.0L	D187018
	D187019	8.4	20	10	33	5.15	6.55	.34	5.9	.86	1.0L	D187019
	D187020	7.5	19	12	35	5.43	7.00	.36	5.8	.86	1.0L	D187020
PW3	D187021	8.7	30	13	31	4.65	5.88	.41	5.0	1.1	1.0L	D187021
	D187022	9.4	27	11	24	4.08	5.83	.93	9.1	.63	1.0L	D187022
	D187023	7.5	18	11	33	4.93	7.05	.40	7.3	.78	1.0L	D187023
	D187024	68.0	64	17	2.1	1.21	.47	3.5	2.9	.69	1.0L	D187024
PW3	D187025	8.9	26	12	30	4.73	5.83	.48	6.4	.81	1.0L	D187025
	D187026	15.8	33	13	14	2.70	3.18	1.5	13	.51	1.0L	D187026
PW10	D187014	31.5	31	8.0	6.1	1.98	1.09	1.7	34	.86	1.0L	D187014
	D187015	8.7	18	10	33	4.20	5.88	.41	6.7	.73	1.0L	D187015
	D187016	9.5	30	14	26	3.75	3.50	.57	6.1	.77	1.0L	D187016
	D189026	8.7	16	7.8	25	4.95	6.38	.42	11	.58	1.0L	D189026
76101	D189027	8.1	21	14	31	5.10	6.50	.30	7.0	.60	1.0L	D189027
	D189028	6.5	17	11	35	5.75	7.58	.32	6.2	.87	1.0L	D189028
	D189029	8.3	22	11	28	4.50	5.55	.23	4.7	1.0	1.0L	D189029
	D189030	13.7	42	15	15	3.08	3.30	1.9	6.8	.64	1.0L	D189030

Hole number	Sample number	SO <sub>3</sub> (percent)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Cu (ppm)	Ga-S (ppm)	Ge-S (ppm)	La-S (ppm)	Sample number
PW2	D187017	14	700	15,000	2	1.0L	N	53	15	N	N	D187017
	D187018	17	1,000	3,000	3	1.0	N	72	20	N	N	D187018
	D187019	13	1,500	15,000	7	1.0L	N	46	N	30	100	D187019
	D187020	5.6	1,500	15,000	2	1.0L	N	46	N	N	70	D187020
PW3	D187021	7.1	1,000	7,000	2	1.0L	N	67	15	N	N	D187021
	D187022	18	1,500	3,000	7	1.0L	N	84	15	N	N	D187022
	D187023	11	1,500	7,000	3	18.0	N	46	20	N	N	D187023
	D187024	2.0	150	1,500	3	1.0L	N	58	30	N	70	D187024
PW3	D187025	15	1,500	3,000	2	1.0L	N	67	30	N	N	D187025
	D187026	21	700	700	15	1.0	N	138	30	N	N	D187026
PW10	D187014	16	200	7,000	7	1.0L	N	68	100	700	100	D187014
	D187015	18	700	7,000	3	1.0L	N	50	15	N	N	D187015
	D187016	14	700	3,000	3	1.0L	N	74	30	N	N	D187016
	D189026	27	1,500	3,000	10	1.0L	B	53	15	50	N	D189026
76101	D189027	14	700	3,000	10	1.0L	B	37	15	20	N	D189027
	D189028	7.1	1,000	7,000	N	1.0L	B	42	15	N	N	D189028
	D189029	17	700	7,000	N	1.0L	B	40	15	N	N	D189029
	D189030	11	700	2,000	5	1.0L	N	58	15	N	N	D189030

Table 8 --Major and minor oxide and trace element composition of the laboratory ash of 18 lignite and shale samples from the Tongue River Member of the Fort Union Formation, Pumpkin Creek EMIA study site, Powder River County, Montana--Continued

Hole number	Sample number	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Ni-S (ppm)	Pb (ppm)	Sc-S (ppm)	Str-S (ppm)	V-S (ppm)	Y-S (ppm)	Sample number
PW2	D187017	63	1,000	7	20	10	40	10	3,000	70	30	D187017
	D187018	80	480	5	20	15	35	20	3,000	70	50	D187018
	D187019	53	805	N	30	10	30	10	7,000	70	70	D187019
	D187020	90	835	5	20	15	35	10	7,000	30	70	D187020
PW3	D187021	116	830	5	20	15	30	10	3,000	70	50	D187021
	D187022	63	765	15	20	30	40	15	3,000	70	70	D187022
PW8	D187023	55	795	30	20	15	60	15	7,000	70	70	D187023
	D187024	45	80	10	20	70	45	15	200	70	70	D187024
	D187025	71	500	15	20	15	35	10	3,000	70	50	D187025
	D187026	53	460	30	20	100	50	15	1,500	150	70	D187026
	D187014	20	2,060	N	100	70	25L	30	700	300	150	D187014
PW10	D187015	45	905	15	20	20	25	15	7,000	70	70	D187015
	D187016	55	720	10	20	30	45	15	3,000	70	50	D187016
	D189026	14	550	10	N	20	25L	20	5,000	150	100	D189026
	D189027	67	825	7	N	10	50	15	3,000	50	50	D189027
76101	D189028	55	1,010	7	N	10	55	7	3,000	30	20	D189028
	D189029	94	940	7	N	7	30	7	3,000	50	20	D189029
	D189030	56	535	10	N	15	45	10	150	70	20	D189030
	D189030											

Hole number	Sample number	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
PW2	D187017	7	98	150
	D187018	5	69	150
	D187019	7	120	300
PW3	D187020	7	102	150
	D187021	3	112	150
PW8	D187022	7	122	150
	D187023	7	2,100	150
	D187024	7	2,221	150
	D187025	5	66	150
	D187026	7	200	70
PW10	D187014	15	193	1,500
	D187015	5	105	150
	D187016	7	186	150
	D189026	7	83	150
76101	D189027	5	94	150
	D189028	2	103	70
	D189029	2	128	100
	D189030	3	144	70

Table 9 --Content of nine trace elements in 18 lignite and shale samples from the Tongue River Member of the Fort Union Formation, Pumpkin Creek EMRIA study site, Powder River County, Montana

[Analyses on air-dried (32°C) lignite. L, Less than the value shown]

Hole number	Sample number	As (ppm)	Co (ppm)	Cr (ppm)	F (ppm)	Hg (ppm)	Sb (ppm)	Se (ppm)	Th (ppm)	U (ppm)	Sample number
PW2	D187017	1.4	0.8	3.3	45	0.09	0.3	0.5	1.7	1.1	D187017
	D187018	1.5	.9	2.7	20	.11	.3	.7	1.4	.5	D187018
	D187019	1.0	.5	2.0	40	.05	.3	.1L	1.3	.5	D187019
	D187020	1.6	.5	1.6	35	.05	.1	.2	1.3	.9	D187020
PW3	D187021	1.0	.7	2.2	35	.09	.3	.4	1.3	.9	D187021
	D187022	2.5	1.0	4.0	45	.12	.7	.4	1.3	1.2	D187022
PW8	D187023	.9	.7	2.9	35	.05	.4	.3	1.4	.6	D187023
	D187024	13	23	48	585	.37	2.2	1.7	9.8	6.0	D187024
	D187025	1.3	.7	1.0L	35	.06	.3	.5	1.5	.7	D187025
	D187026	18	7.6	10	80	.46	2.1	1.0	2.8	4.7	D187026
PW10	D187014	420	8.1	50	155	1.40	6.2	1.1	2.4	5.6	D187014
	D187015	1.4	.7	2.1	55	.09	.3	.4	1.4	1.0	D187015
	D187016	2.6	1.9	3.3	40	.15	.6	.1L	1.3	1.1	D187016
	D189026	7.1	1.1	5.3	50	.08	.5	.4	1.9	1.2	D189026
76101	D189027	1.6	.5	1.7	35	.07	.3	.3	1.7	1.4	D189027
	D189028	1.0	.6	1.4	45	.04	.2	.1L	.8	.7	D189028
	D189029	1.3	.7	2.0	40	.08	.2	.4	1.1	1.1	D189029
	D189030	7.3	1.3	8.3	95	.24	1.1	.5	1.9	2.0	D189030

Table 10--Major, minor, and trace element composition of 18 coal and shale samples from the Tongue River Member of the Fort Union Formation, Pumpkin Creek EMRIA study site, Powder River County, Montana

[Values in percent or parts per million. As, Co, Cr, F, Hg, Sb, Se, Th, and U values are from direct determinations on air dried (32°C) coal; all other values calculated from analyses of ash. S means analysis by emission spectrography; L, less than the value shown; N, not detected; B, not determined]

Hole number	Sample number	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	As (ppm)	B-S (ppm)	Sample number
PW2	D187017	1.4	0.61	1.9	0.27	0.36	0.068	0.40	0.075	1.4	70	D187017
	D187018	1.1	.63	1.6	.28	.35	.023	.41	.039	1.5	100	D187018
	D187019	.78	.44	2.0	.26	.41	.024	.35	.043	1.0	150	D187019
	D187020	.67	.48	1.9	.25	.39	.022	.30	.029	1.6	100	D187020
PW3	D187021	1.2	.60	1.9	.24	.38	.030	.30	.037	1.0	100	D187021
	D187022	1.2	.55	1.6	.23	.41	.073	.60	.035	2.5	150	D187022
	D187023	.63	.44	1.8	.22	.39	.025	.38	.035	1.3	100	D187023
	D187024	20	6.1	1.0	.50	.24	2.0	1.4	.28	13	100	D187024
PW8	D187025	1.1	.56	1.9	.25	.38	.036	.40	.043	1.3	150	D187025
	D187026	2.4	1.1	1.6	.26	.37	.020	1.4	.048	18	100	D187026
PW10	D187014	4.6	1.3	1.4	.38	.25	.45	7.5	.16	420	70	D187014
	D187015	.73	.46	2.0	.22	.38	.030	.41	.038	1.4	70	D187015
	D187016	1.3	.70	1.8	.21	.25	.045	.41	.043	2.6	70	D187016
	D189026	.65	.36	1.6	.26	.41	.030	.67	.030	7.1	70	D189026
76101	D189027	.79	.60	1.8	.25	.39	.020	.40	.029	1.6	70	D189027
	D189028	.52	.38	1.6	.22	.37	.017	.28	.034	1.0	70	D189028
	D189029	.85	.48	1.7	.22	.34	.016	.27	.030	1.3	70	D189029
	D189030	2.7	1.1	1.5	.23	.34	.22	.65	.053	7.3	100	D189030

Hole number	Sample number	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co (ppm)	Cr (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	Ge-S (ppm)	Sample number
PW2	D187017	1,500	0.3	0.11L	N	0.8	3.3	5.6	45	1.5	N	D187017
	D187018	300	.3	.09	N	.9	2.7	6.6	20	2	N	D187018
	D187019	1,500	.7	.08L	N	.5	2.0	3.9	40	N	2	D187019
	D187020	1,000	.15	.07L	N	.5	1.6	3.5	35	N	N	D187020
PW3	D187021	700	.15	.09L	N	.7	2.2	5.8	35	1.5	N	D187021
	D187022	300	.7	.09L	N	1.0	4.0	7.9	45	1.5	N	D187022
	D187023	500	.2	1.4	N	.7	2.9	3.5	35	1.5	N	D187023
	D187024	1,000	.2	.68L	N	23	48	39	585	20	N	D187024
PW8	D187025	100	.2	.09L	N	.7	1.0L	6.0	80	3	N	D187025
	D187026	300	.2	.16	N	7.6	10	22	80	5	N	D187026
PW10	D187014	2,000	2	.31L	N	8.1	50	21	155	30	200	D187014
	D187015	700	.2	.09L	N	.9	2.1	4.4	55	1.5	N	D187015
	D187016	300	.3	.09L	N	1.9	3.3	7.0	40	3	N	D187016
	D189026	150	.7	.08L	B	1.1	5.3	4.6	50	1.5	5	D189026
76101	D189027	200	.7	.08L	B	.5	1.7	3.0	35	1.5	1.5	D189027
	D189028	500	N	.07L	B	.6	1.4	2.7	45	1	N	D189028
	D189029	700	N	.08L	B	.7	2.0	3.3	40	1.5	N	D189029
	D189030	300	.7	.14L	N	1.3	8.3	7.9	95	2	N	D189030

Table 10--Major, minor, and trace element composition of 18 coal and shale samples from the Tongue River Member of the Fort Union Formation,  
Pueblin Creek ERIA study site, Powder River County, Montana--Continued

Hole number	Sample number	Hg (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Kb-S (ppm)	Ni-S (ppm)	P (ppm)	Pb (ppm)	Sb (ppm)	Sample number
PWW2	D187017	0.09	N	6.6	110	0.7	2	1.5	460L	4.2	0.3	D187017
	D187018	.11	N	7.3	44	.5	2	1.5	460L	3.2	.3	D187018
	D187019	.05	10	4.5	68	N	2	1	370L	2.5	.3	D187019
PWW3	D187020	.05	S	6.8	63	.3	1.5	1.5	370L	2.6	.1	D187020
	D187021	.09	N	10	72	.5	1.5	1.5	382L	2.6	.3	D187021
PWW6	D187022	.12	N	5.9	72	1.5	2	3	410L	3.8	.7	D187022
	D187023	.05	N	4.1	60	2	1.5	1	330L	4.5	.4	D187023
	D187024	.37	50	31	54	7	15	50	3,060	31	2.2	D187024
PWW10	D187025	.06	N	6.3	45	1.5	2	1.5	390L	3.1	.3	D187025
	D187026	.46	N	8.4	73	5	3	15	690L	7.9	2.1	D187026
76101	D187014	1.4	30	6.3	650	N	30	20	1,400L	7.9L	6.2	D187014
	D187015	.09	N	3.9	79	1.5	1.5	1.5	390L	2.2	.3	D187015
	D187016	.15	N	5.2	68	1	2	3	420L	4.3	.6	D187016
76101	D189026	.08	N	1.2	48	1	N	1.5	350L	2.2L	.5	D189026
	D189027	.07	N	5.4	67	.7	N	.7	350L	4.1	.3	D189027
	D189028	.04	N	3.6	66	.5	N	.7	280L	3.6	.2	D189028
D189030	D189029	.08	N	7.8	78	.7	N	.7	360L	2.5	.2	D189029
	D189030	.24	N	7.7	73	1.5	N	2	600L	6.2	1.1	D189030

Hole number	Sample number	Sc-S (ppm)	Se (ppm)	Sr-S (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)	Sample number
PWW2	D187017	1	0.5	300	1.7	1.1	7	3	0.7	10	15	D187017
	D187018	N	.7	300	1.4	.5	7	5	.5	6.3	15	D187018
	D187019	1.5	.1L	700	1.3	.5	7	7	.7	10	20	D187019
PWW3	D187020	.7	.2	500	1.3	.9	2	5	.5	7.7	10	D187020
	D187021	1	.4	200	1.3	.9	7	5	.2	9.7	15	D187021
PWW8	D187022	1.5	.4	200	1.3	1.2	7	7	.7	11	15	D187022
	D187023	10	.3	500	9.8	6.6	5	5	.5	160	10	D187023
	D187024	1	1.7	150	1.5	.7	50	50	5	150	100	D187024
PWW10	D187025	2	1.5	300	2.8	4.7	7	10	.5	5.9	15	D187025
	D187026	10	1.0	200	2.4	5.6	20	5	1	32	10	D187026
76101	D187014	10	1.1	200	1.4	1.0	100	50	5	61	500	D187014
	D187015	1.5	.4	700	1.3	1.1	7	7	.5	9.1	15	D187015
	D187016	1.5	.1L	300	1.3	1.2	15	5	.7	18	15	D187016
D189030	D189026	1.5	.4	500	1.7	1.4	5	10	.7	7.2	15	D189026
	D189027	1.5	.3	200	1.7	1.4	5	5	.5	7.6	15	D189027
	D189028	.5	.1L	200	.8	.7	2	1.5	.15	6.7	5	D189028
D189030	D189029	1.5	.4	200	1.1	1.1	3	1.5	.15	11	10	D189029
	D189030	1.5	.5	20	1.9	2.0	10	3	.7	20	10	D189030

Table 11 -Elements looked for, but not detected, in lignite samples from the Tongue River Member of the Fort Union Formation, Pumpkin Creek EMRIA study site, Powder River County, Montana

[Approximate lower detection limits for these elements in lignite ash by the six-step spectrographic method of the U.S. Geological Survey are included]

Element	Lower limit of detection (ppm) in lignite ash
Ag	1
Au	50
Bi	20
Ce	500
Dy	100
Er	100
Eu	200
Gd	100
Hf	200
Ho	50
In	20
Lu	70
Nd	150
Pd	5
Pr	200
Pt	100
Re	100
Sm	200
Sn	20
Ta	1,000
Tb	700
Te	5,000
Tm	50
W	200

Table 12--Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion temperatures for 15 Sawyer bed lignite samples from the Fort Union Formation in the Pumpkin Creek EMRIA study site, Powder River County, Montana

[All values are in percent except Kcal/kg, Btu/lb, and ash-fusion temperatures and are reported on the as-received basis. °C = (°F-32) 5/9; Kcal/kg = 0.556 (Btu/lb). Leaders (--) indicate no data. For comparison, arithmetic means from 33 Powder River region coal samples (Swanson and others, 1976, tables 31B and 32B) are included]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
Proximate and ultimate analyses						
Moisture	35.7	30.3	38.4	35.6	1.1	23.1
Volatile matter	26.8	23.9	32.3	26.8	1.1	32.6
Fixed carbon	30.6	27.5	33.3	30.6	1.1	36.0
Ash	6.8	4.4	14.2	6.5	1.4	7.5
Hydrogen	6.8	6.4	7.0	6.8	1.0	6.2
Carbon	41.2	36.9	43.4	41.1	1.1	50.3
Nitrogen	.7	.6	.7	.7	1.1	.9
Oxygen	44.1	41.4	46.4	44.1	1.0	32.9
Sulfur	.4	.2	1.7	.4	1.8	.8
Heat of combustion						
Kcal/kg	3,880	3,480	4,040	3,880	1.0	4,860
Btu/lb	6,970	6,260	7,260	6,970	1.0	8,740
Forms of sulfur						
Sulfate	0.01	0.01	0.01	0.01	1.0	0.02
Pyritic	.16	.06	.53	.13	1.9	.29
Organic	.26	.05	1.16	.19	2.3	.31
Ash-fusion temperature °C						
Initial deformation	1,164	1,074	1,213	1,163	1.0	-----
Softening temperature	1,222	1,132	1,271	1,221	1.0	-----
Fluid temperature	1,276	1,179	1,324	1,276	1.0	-----

Table 13 --Arithmetic mean, observed range, geometric mean, and geometric deviation of ash content and contents of nine major and minor oxides in the laboratory ash of 15 Sawyer bed lignite samples from the Tongue River Member of the Fort Union Formation in the Pumpkin Creek EMRIA study site, Powder River County, Montana

[All samples were ashed at 525°C; all analyses are in percent. For comparison, geometric means for 410 Powder River region coal samples are listed (Hatch and Swanson, 1977, table 6a)]

Oxide	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
(Ash)	9.4	6.5	15.8	9.1	1.3	9.0
SiO <sub>2</sub>	25	17	42	24	1.3	28
Al <sub>2</sub> O <sub>3</sub>	12	10	15	12	1.1	14
CaO	28	14	35	27	1.3	15
MgO	4.5	2.7	5.8	4.4	1.2	3.6
Na <sub>2</sub> O	5.6	3.2	7.6	5.4	1.3	.93
K <sub>2</sub> O	.6	.23	1.9	.5	1.9	.28
Fe <sub>2</sub> O <sub>3</sub>	6.8	4.7	13	6.6	1.3	5.8
TiO <sub>2</sub>	.81	.51	1.2	.79	1.3	.61
SO <sub>3</sub>	14	5.6	21	13	1.5	14

Table 14 --Arithmetic mean, observed range, geometric mean, and geometric deviation of 27 elements in 15 Sawyer bed lignite samples from the Tongue River Member of the Fort Union Formation, Pumpkin Creek EMRIA study site, Powder River County, Montana

[All analyses are in parts per million and are reported on a whole-lignite basis. As, Co, Cr, F, Hg, Sb, Se, Th, and U values used to calculate the statistics were determined directly on whole lignite. All other values used were calculated from determinations made on lignite ash. L, less than the value shown. For comparison, geometric means for 410 Powder River region coal samples are listed (Hatch and Swanson, 1977, table 6b)]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
As	2.5	0.6	17.5	1.7	2.4	2
B	100	70	150	100	1.3	50
Ba	700	100	1500	500	2.1	300
Be	.5	.15	2	.3	2.2	.5
Co	1.1	.5	7.6	.9	2.0	2
Cr	3.4	1.0L	10	2.8	1.8	5
Cu	6.1	2.7	22	5.3	1.7	9.5
F	45	20	95	42	1.4	40
Ga	2	1L	5	2	1.5	2
Hg	.1	.04	.46	.09	1.9	.08
Li	6.3	3.6	10	6.0	1.4	3.9
Mn	69	44	105	67	1.2	34
Mo	1.5	.3L	5	1	2.1	1.5
Nb	2	1.5L	3	2	1.2	1
Ni	2	.7	15	1.5	2.2	3
Pb	3.8	2.2	7.9	3.6	1.4	5.1
Sb	.5	.1	2.1	.4	2.1	.4
Sc	1.5	.5L	2	1.1	1.5	1.5
Se	.5	.2	1.0	.4	1.5	.7
Sr	300	20	700	200	2.3	150
Th	1.5	.8	2.8	1.4	1.3	3.3
U	1.2	.5	4.7	1.0	1.8	.6
V	7	2	20	7	1.8	10
Y	5	1.5	10	5	1.7	3
Yb	.5	.15	1	.5	1.8	.3
Zn	18	5.9	160	12	2.3	13
Zr	15	5	20	15	1.4	15

7,260 Btu/lb), averaging 3,880 Kcal/kg (6,970 Btu/lb). The lignite below the lower parting in PWW8 has a relatively high sulfur content (1.7 percent), and presumably would not be mined with the lignite above the parting. The analysis of the Mackin-Walker bed shows that its ash content is 6.9 percent, its sulfur content is 1.0 percent, and its heat of combustion is 4,010 Kcal/kg (7,220 Btu/lb). The apparent ranks of the samples were calculated using the data in Table 5 and the formulas in ASTM designation D-388-77 (American Society for Testing and Materials, 1977). The apparent rank of all 17 samples is lignite A.

In Table 12, the geometric means of the proximate and ultimate analyses for the Sawyer bed samples are compared with the geometric means of analyses of 33 coal samples from other areas in the Powder River region, as listed in Swanson and others (1976). The apparent rank of these 33 samples ranges from subbituminous C to subbituminous B coal. Because the Sawyer bed in the Pumpkin Creek area is of lower rank than the average of the 33 samples, its moisture, hydrogen, and oxygen contents are significantly higher (Student's  $t$  test, 95 percent confidence level) and volatile matter, fixed carbon, carbon contents, and heat of combustion are significantly lower than in the 33 other Powder River region samples. Contents of nitrogen and total sulfur are also significantly lower in the Sawyer bed samples.

In Table 13, the geometric means of the contents of nine major and minor oxides in the laboratory ash of 15 Sawyer bed samples are compared with the geometric means of these oxides in 410 Powder River region samples. The contents are similar (Student's test, 95 percent confidence level), except for those  $\text{CaO}$ ,  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ , and  $\text{TiO}_2$ , which are significantly higher in the Sawyer bed. At the 99 percent confidence level only the  $\text{CaO}$  and  $\text{Na}_2\text{O}$  contents are significantly higher.

In Table 14, the geometric means of the contents of 27 elements in the Sawyer bed samples are compared with the geometric means of these elements in 410 Powder River region samples. In the Sawyer bed the contents of B, Ba, Mn, Nb, U, Y, and Yb are significantly higher, and contents of Be, Co, Cr, Cu, Ni, Pb, Sc, Se, and Th are significantly lower. Contents of As, F, Ga, Hg, Li, Mo, Sb, Sr, V, Zn, and Zr are similar for both sets. At the 99 percent confidence level, B, Mn, Y, Yb, Co, Cr, Cu, Ni, and Th contents are significantly different.

When compared to other U.S. coals (Swanson and others, 1976), Powder River region coals are characterized by relatively low ash, low sulfur, and high moisture contents, and a low heat of combustion. The contents of elements of environmental concern (such as As, Be, Cd, Hg, Mo, Sb, and Se) in Powder River region coals are low when compared to other U.S. coals. Powder River region coals are, or will be, used in coal-fired power generating plants or in coal gasification plants.

Differences in the oxide compositions of coal ashes and the element contents of coals result from differences in the total and relative amounts of the various inorganic minerals, the elemental composition of these minerals, and the total relative amounts of any organically bound

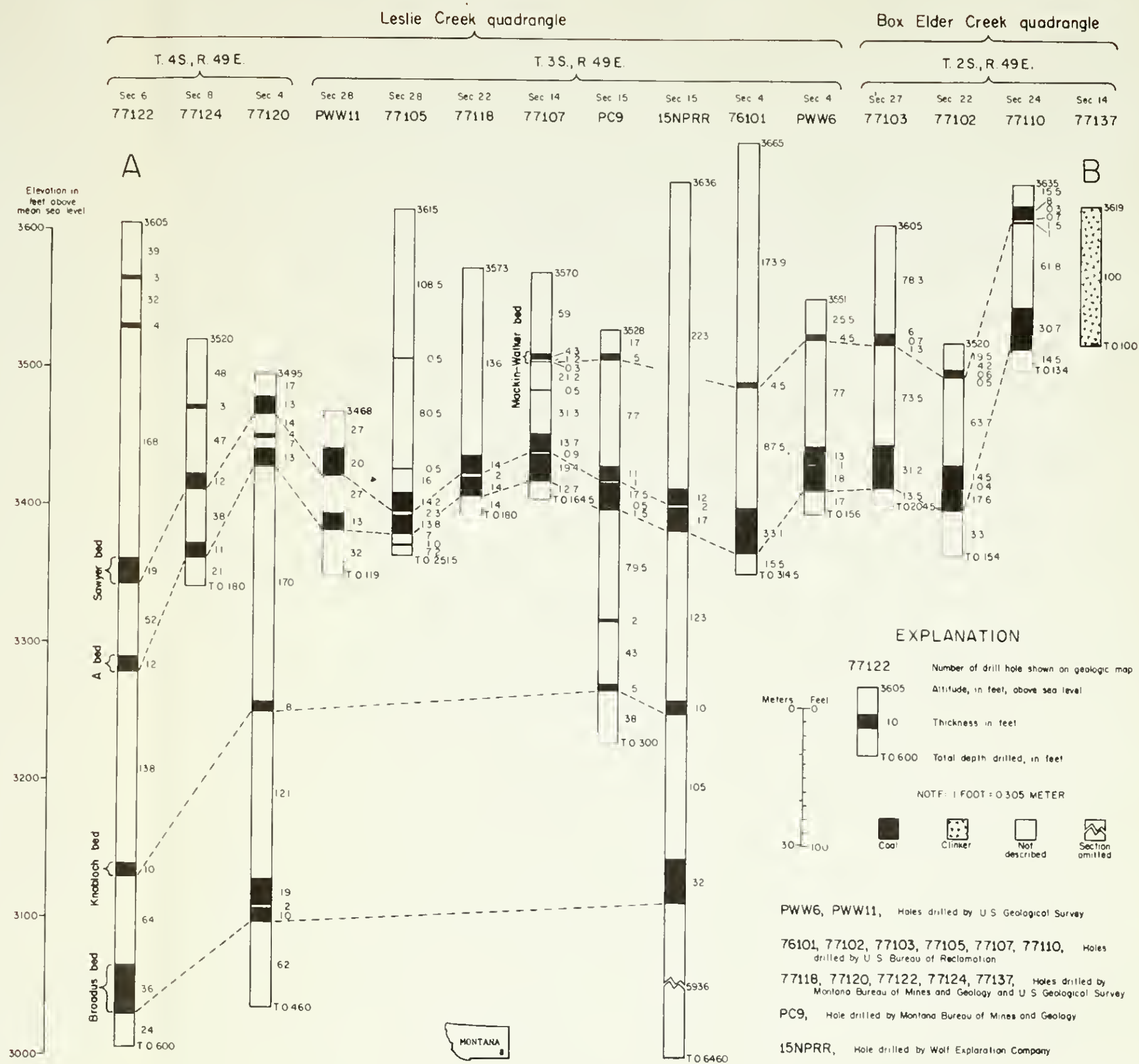
elements. The chemical form and distribution of a given element is dependent on the geologic history of the coalbed. A partial listing of the geologic factors that influence element distributions would include chemical composition of original plants; amounts and compositions of the various detrital, diagenetic, and epigenetic minerals; chemical characteristics of the ground waters that come in contact with the bed; temperatures and pressures reached during burial; and extent of weathering.



APPENDIX D

OVERBURDEN - SOIL AND BEDROCK

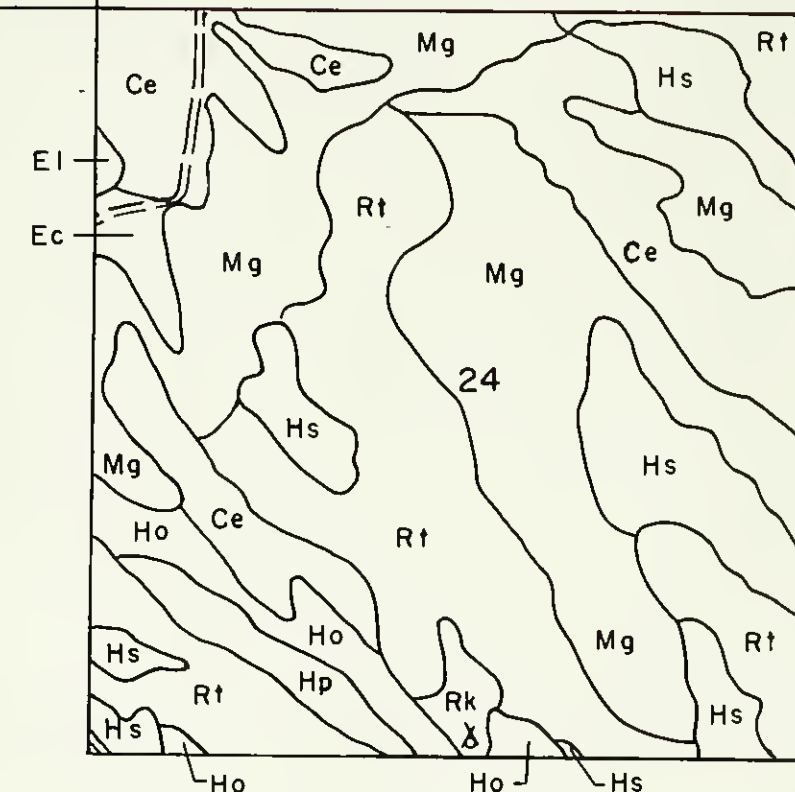
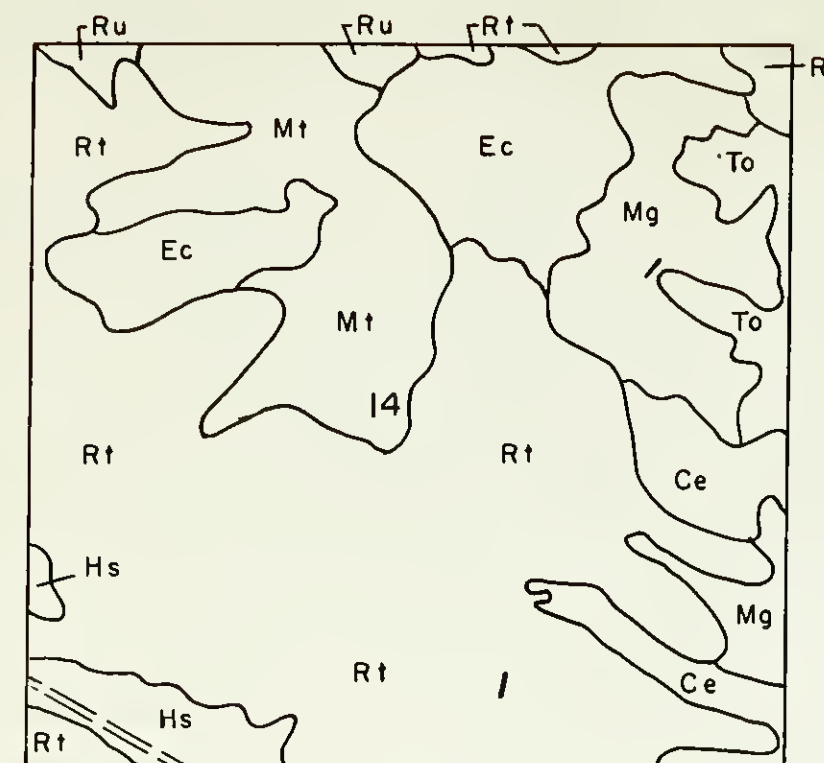
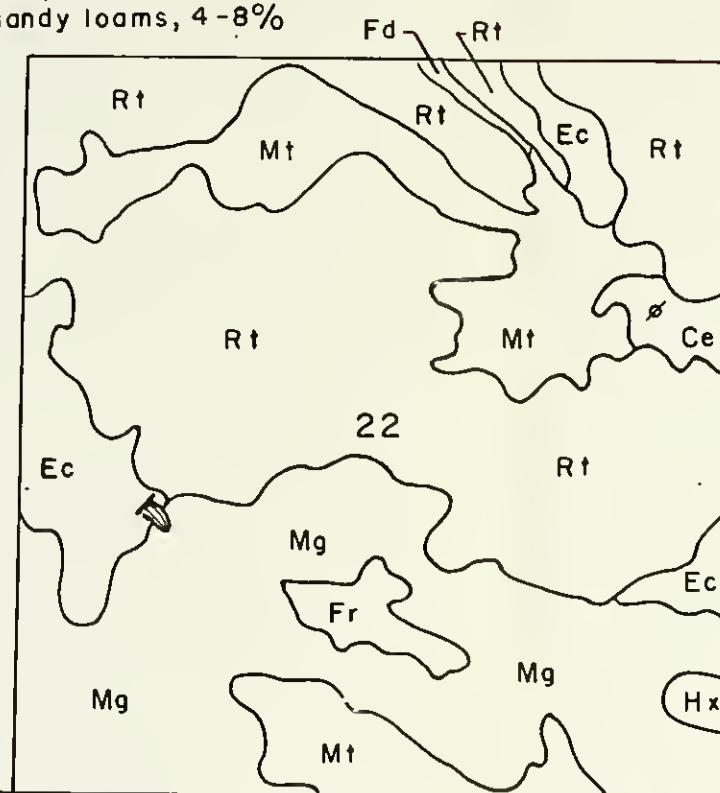
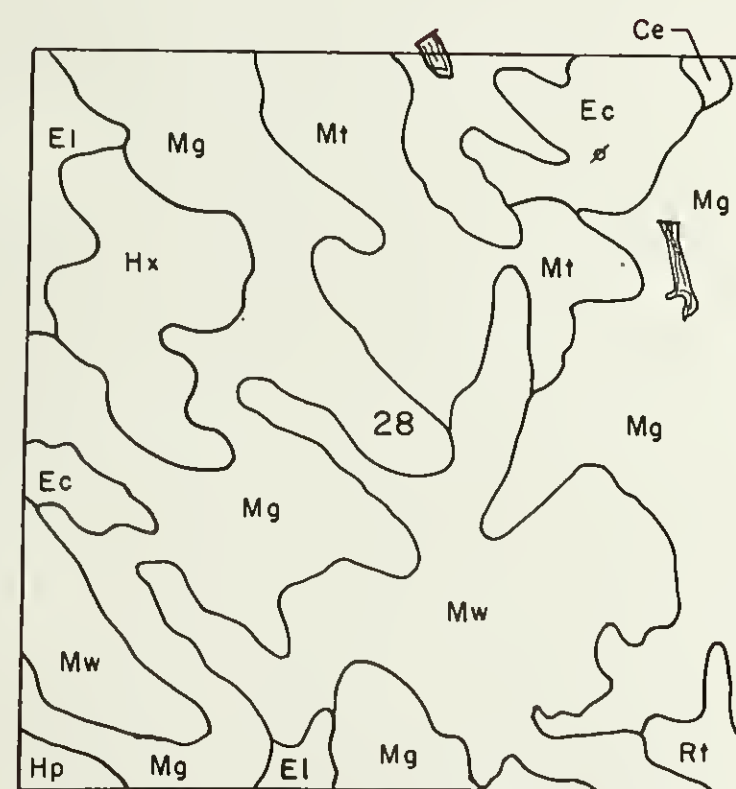




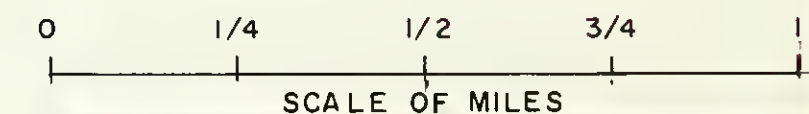
Section along line A—B showing coal beds in drill holes in Pumpkin Creek EMRIA Study Site, Powder River County, Montana



SYMBOL	SERIES/ASSOCIATION	LEGEND	SYMBOL	SERIES/ASSOCIATION
Ab	Arvado-Bone complex, 0-4%		Hw	Hydro-Arvada complex, 2-8%
Be	Bew silty clay, 2-4%		Hx	Hydro-Elso, 8-15%
Bw	Bew silty clay, 4-8%		Hy	Hydro-Fort Collins silt loams, 0-2%
Ce	Cushman-Elso silt loams, 4-8%		Km	Kyle clay, 4-8%
Ec	Elso silt loam, 8-15%		Mc	McRoe silt loam, 0-2%
El	Elso silt loam, 15-45%		Md	McRae silt loam, 2-4%
Eo	Elso-Ocean lake, 15-45%		Mf	Midway silty clay loam, 2-8%
Fd	Farland silt loam, 2-4%		Mg	Midway-Elso, 8-35%
Fr	Fort Collins silt loam, 2-4%		Mt	Midway-Thurlow, 8-15%
Ga	Galata silty clay, 4-8%		Mw	Midway-Elso rocky soils, 35-75%
Hc	Haverson silt loam		Rc	Rapelje silt loam, 2-8%
Hf	Haverson soils channeled		Rh	Relan-Cabba, 4-8%
Hk	Heldt silty clay loam, 2-4%		Rk	Relan gravelly loam, 4-8%
Hm	Heldt silty clay loam, 4-8%		Ro	Remmit-Ocean lake fine sandy loams, 8-25%
Hn	Hesper silty clay loam, 0-2%		Rs	Ringling silty loam, 20-50%
Ho	Hesper silty clay loam, 2-4%		Rt	Ringling-Cabba, 15-50%
Hp	Hesper silty clay loam, 4-8%		Ru	Ringling-Relan, 6-25%
Hr	Hesper silty clay loam, 8-15%		Tm	Thurlow silty clay loam, 2-4%
Hs	Hopley-Relan loams, 4-8%		To	Thurlow silty clay loam, 4-8%
Ht	Hydro silty clay loam, 0-2%		Tr	Thurlow silty clay loam, 8-15%
Hu	Hydro silty clay loam, 2-4%		Vr	Vona-Remmit fine sandy loams, 4-8%
Hv	Hydro silty clay loam, 4-8%			



- CONVENTIONAL SYMBOLS
- WORKS AND STRUCTURES
- Improved road
  - Unimproved road
  - Windmill
  - Dams
- LAND FEATURES
- Gumbo, slick or scabby spot (sodic)
- WATER FEATURES
- Perennial lake or pond
  - Intermittent lake or pond



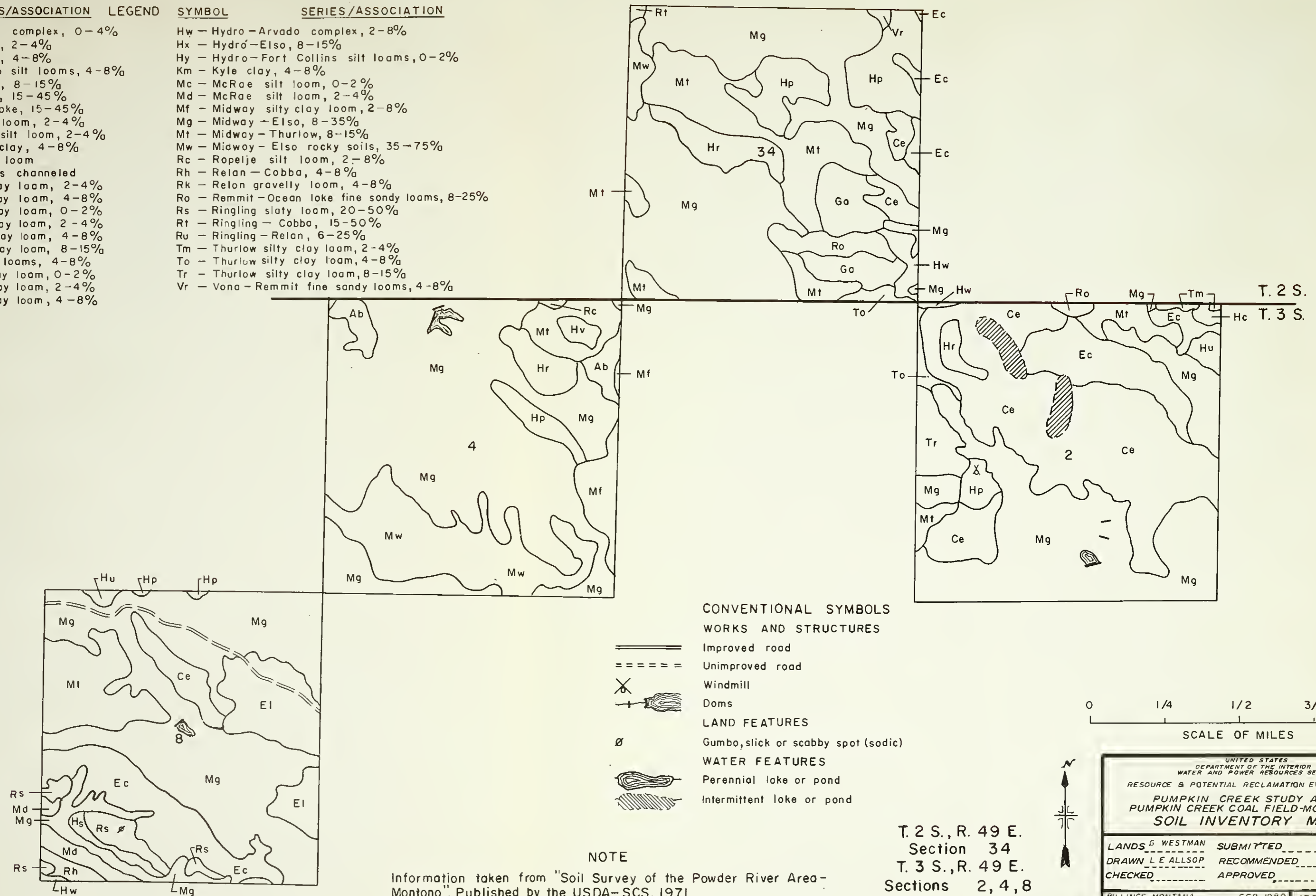
Information taken from "Soil Survey of the Powder River Area-Montana, Published by the USDA-SCS, 1971.

T. 2 S., R. 49 E.  
Sections 14, 22, 24, 28

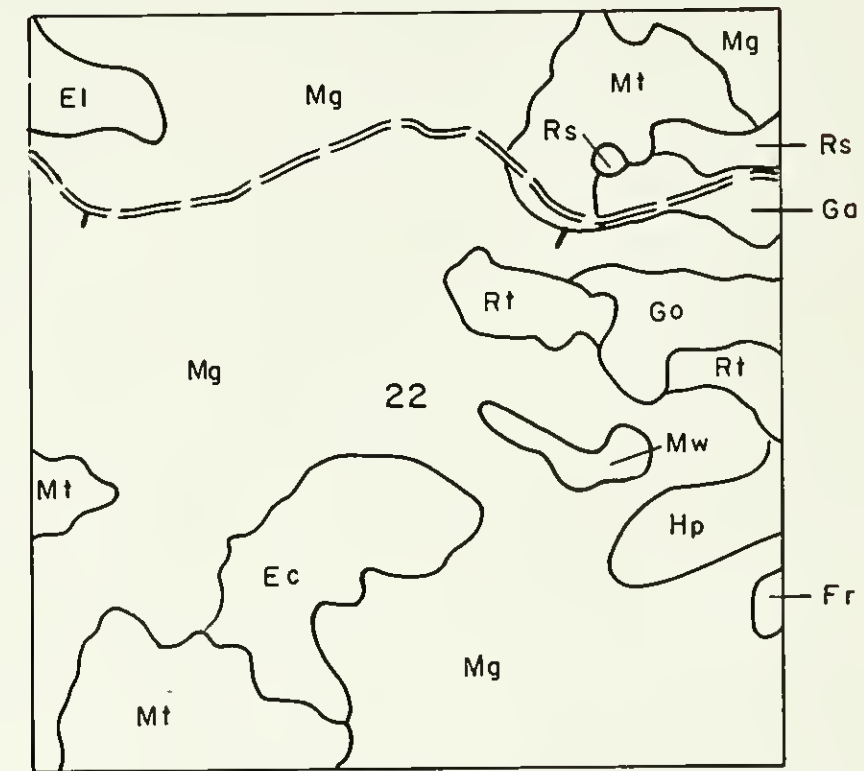
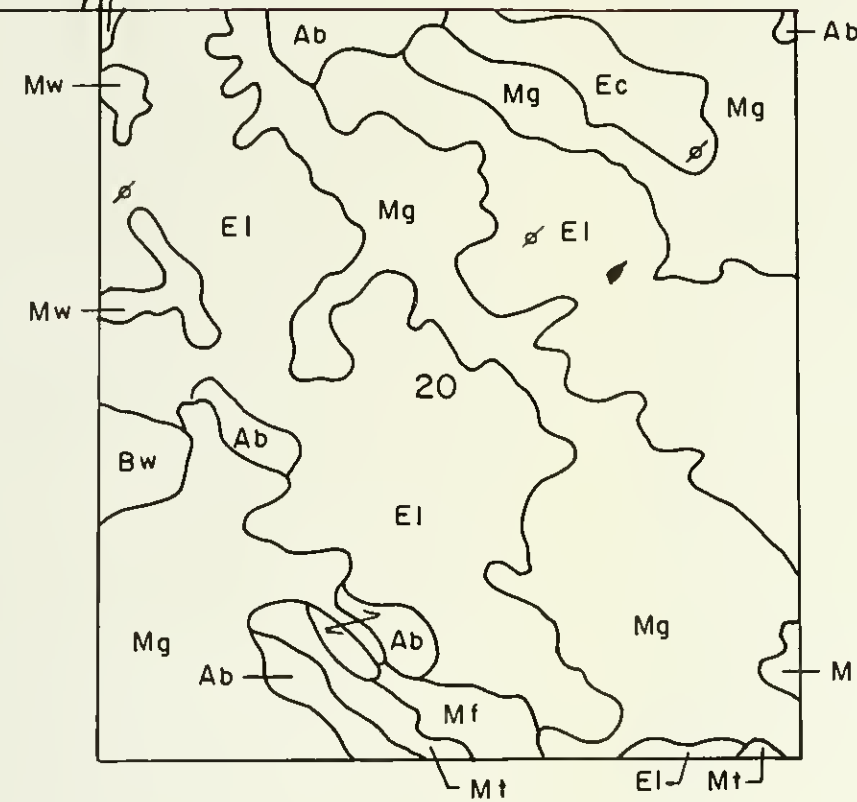
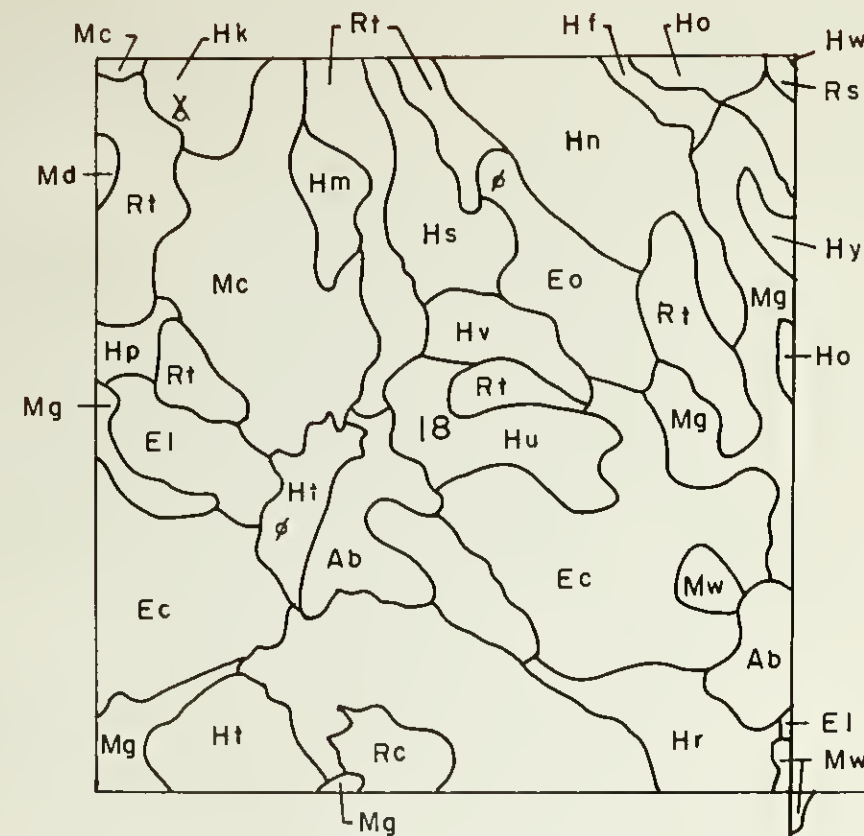
UNITED STATES DEPARTMENT OF THE INTERIOR WATER AND POWER RESOURCES SERVICE	
RESOURCE & POTENTIAL RECLAMATION EVALUATION	
PUMPKIN CREEK STUDY AREA PUMPKIN CREEK COAL FIELD-MONTANA SOIL INVENTORY MAP	
LANDS G. WESTMAN	SUBMITTED
DRAWN L. E. ALLSOP	RECOMMENDED
CHECKED	APPROVED
BILLINGS, MONTANA	FEB., 1980 1305-600-239



SYMBOL	SERIES/ASSOCIATION	LEGEND	SYMBOL	SERIES/ASSOCIATION
Ab	Arvado-Bone complex, 0-4%		Hw	Hydro-Arvido complex, 2-8%
Be	Bew silty clay, 2-4%		Hx	Hydro-Elso, 8-15%
Bw	Bew silty clay, 4-8%		Hy	Hydro-Fort Collins silt loams, 0-2%
Ce	Cushman-Elso silt loams, 4-8%		Km	Kyle clay, 4-8%
Ec	Elso silt loam, 8-15%		Mc	McRae silt loam, 0-2%
El	Elso silt loam, 15-45%		Md	McRae silt loam, 2-4%
Eo	Elso-Ocean loke, 15-45%		Mf	Midway silty clay loam, 2-8%
Fd	Farland silt loam, 2-4%		Mg	Midway-Elso, 8-35%
Fr	Fort Collins silt loam, 2-4%		Mt	Midway-Thurlow, 8-15%
Ga	Galata silty clay, 4-8%		Mw	Midway-Elso rocky soils, 35-75%
Hc	Haverson silt loam		Rc	Rapelje silt loam, 2-8%
Hf	Haverson soils channeled		Rh	Relan-Cobba, 4-8%
Hk	Heldt silty clay loam, 2-4%		Rk	Relan gravelly loam, 4-8%
Hm	Heldt silty clay loam, 4-8%		Ro	Remmit-Ocean loke fine sandy loams, 8-25%
Hn	Hesper silty clay loam, 0-2%		Rs	Ringling slaty loam, 20-50%
Ho	Hesper silty clay loam, 2-4%		Rt	Ringling-Cobba, 15-50%
Hp	Hesper silty clay loam, 4-8%		Ru	Ringling-Relan, 6-25%
Hr	Hesper silty clay loam, 8-15%		Tm	Thurlow silty clay loam, 2-4%
Hs	Hopley-Relan loams, 4-8%		To	Thurlow silty clay loam, 4-8%
Ht	Hydro silty clay loam, 0-2%		Tr	Thurlow silty clay loam, 8-15%
Hu	Hydro silty clay loam, 2-4%		Vr	Vona-Remmit fine sandy loams, 4-8%
Hv	Hydro silty clay loam, 4-8%			

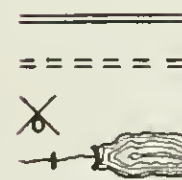






SYMBOL	SERIES/ASSOCIATION	LEGEND	SYMBOL	SERIES/ASSOCIATION
Ab	Arvada-Bone complex, 0-4%		Hw	Hydro-Arvada complex, 2-8%
Be	Bew silty clay, 2-4%		Hx	Hydro-Elso, 8-15%
Bw	Bew silty clay, 4-8%		Hy	Hydro-Fort Collins silt loams, 0-2%
Ce	Cushman-Elso silt loams, 4-8%		Km	Kyle clay, 4-8%
Ec	Elso silt loam, 8-15%		Mc	McRae silt loam, 0-2%
El	Elso silt loam, 15-45%		Md	McRae silt loam, 2-4%
Eo	Elso-Ocean lake, 15-45%		Mf	Midway silty clay loam, 2-8%
Fd	Forland silt loam, 2-4%		Mg	Midway-Elso, 8-35%
Fr	Fort Collins silt loam, 2-4%		Mt	Midway-Thurlow, 8-15%
Ga	Galata silty clay, 4-8%		Mw	Midway-Elso rocky soils, 35-75%
Hc	Hoverson silt loam		Rc	Rapelje silt loam, 2-8%
Hf	Haverson soils channeled		Rh	Relan-Cabba, 4-8%
Hk	Heldt silty clay loam, 2-4%		Rk	Relan gravelly loam, 4-8%
Hm	Heldt silty clay loam, 4-8%		Ro	Remmit-Ocean lake fine sandy loams, 8-25%
Hn	Hesper silty clay loam, 0-2%		Rs	Ringling silty loam, 20-50%
Ho	Hesper silty clay loam, 2-4%		Rt	Ringling-Cabba, 15-50%
Hp	Hesper silty clay loam, 4-8%		Ru	Ringling-Relan, 6-25%
Hr	Hesper silty clay loam, 8-15%		Tm	Thurlow silty clay loam, 2-4%
Hs	Hopley-Relan loams, 4-8%		To	Thurlow silty clay loam, 4-8%
Ht	Hydro silty clay loam, 0-2%		Tr	Thurlow silty clay loam, 8-15%
Hu	Hydro silty clay loam, 2-4%		Vr	Vona-Remmit fine sandy loams, 4-8%
Hv	Hydro silty clay loam, 4-8%			

CONVENTIONAL SYMBOLS  
WORKS AND STRUCTURES



LAND FEATURES

Ø Gumbo, slick or scabby spot (sodic)

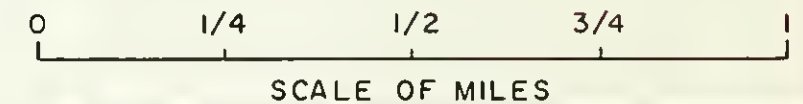
WATER FEATURES



NOTE

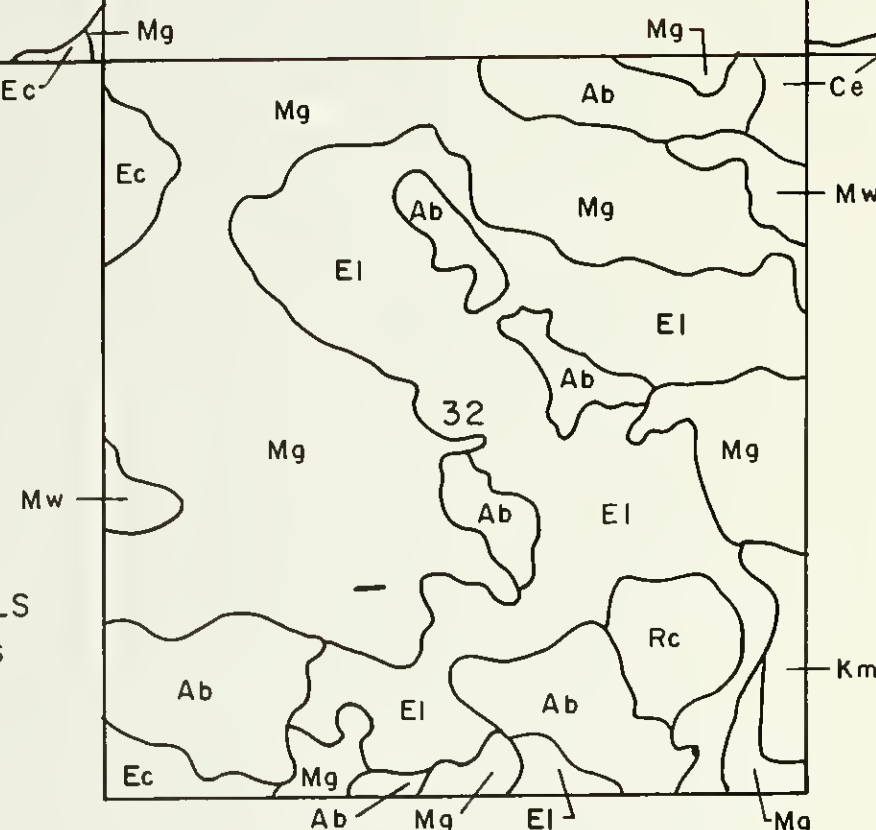
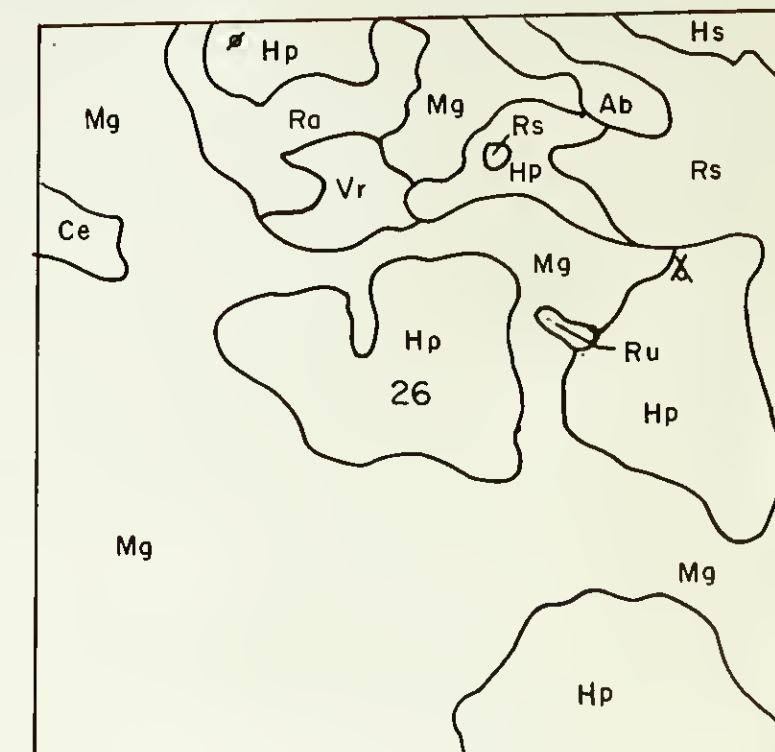
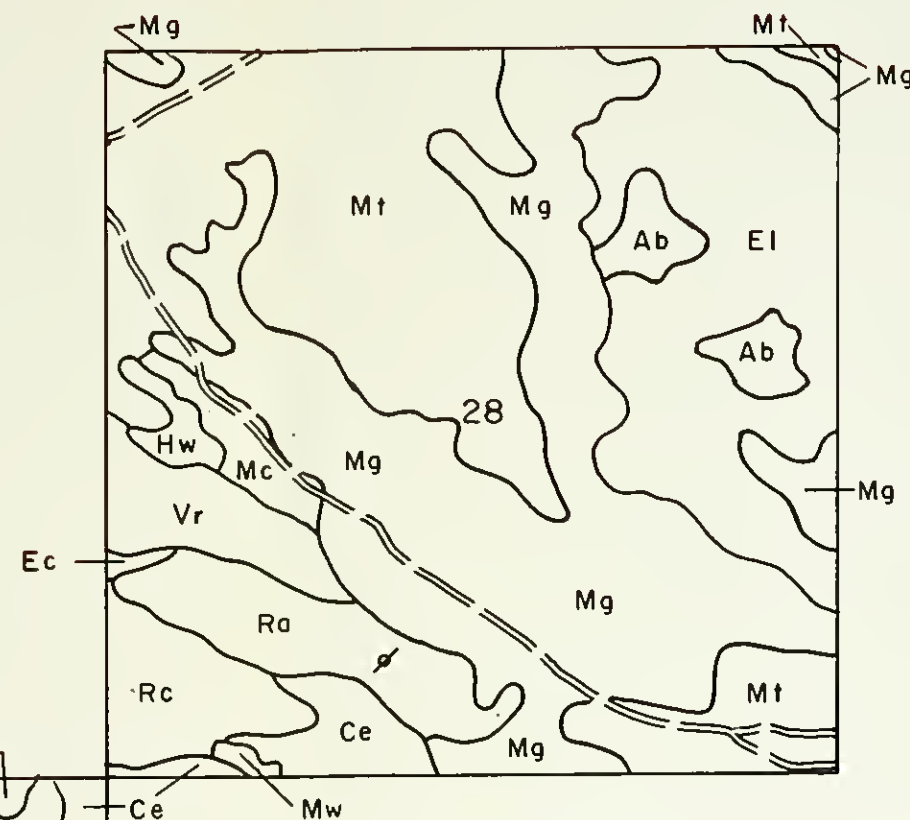
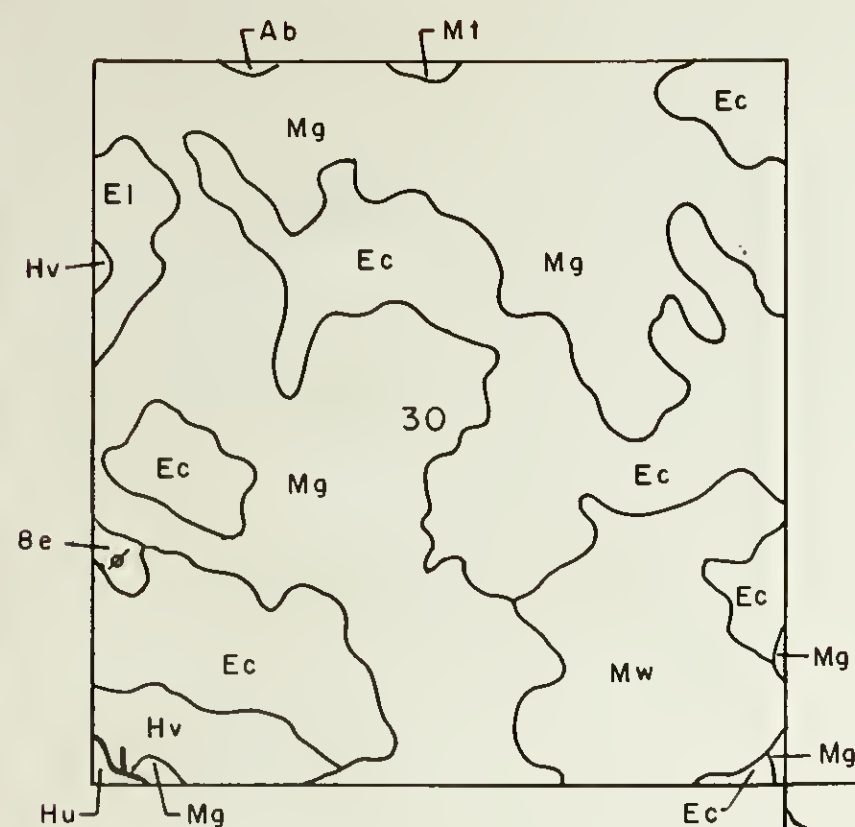
Information taken from "Soil Survey of the Powder River Area-Montana," Published by the USDA-SCS, 1971.

T. 3 S., R. 49 E.  
Sections 18, 20, 22

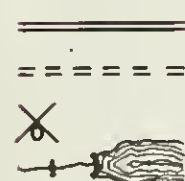


UNITED STATES DEPARTMENT OF THE INTERIOR WATER AND POWER RESOURCES SERVICE	
RESOURCE & POTENTIAL RECLAMATION EVALUATION	
PUMPKIN CREEK STUDY AREA PUMPKIN CREEK COAL FIELD-MONTANA SOIL INVENTORY MAP	
LANDS G WESTMAN	SUBMITTED
DRAWN L E ALLSOP	RECOMMENDED
CHECKED	APPROVED
BILLINGS, MONTANA FEB., 1980 1305-600-241	





# CONVENTIONAL SYMBOLS WORKS AND STRUCTURES



## LAND FEATURES

Ø Gumbo, slick or scobby spot (sodic)

## WATER FEATURES



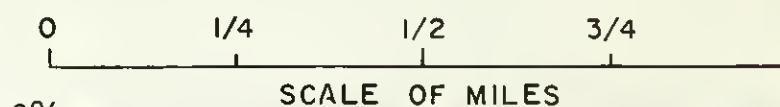
Perennial lake or pond  
Intermittent lake or pond

# SYMBOL SERIES/ASSOCIATION

Ab - Arvada - Bone complex, 0-4%  
Be - Bew silty clay, 2-4%  
Bw - Bew silty clay, 4-8%  
Ce - Cushman - Elso silt loams, 4-8%  
Ec - Elso silt loam, 8-15%  
Ei - Elso silt loam, 15-45%  
Eo - Elso - Ocean lake, 15-45%  
Fd - Farland silt loam, 2-4%  
Fr - Fort Collins silt loam, 2-4%  
Ga - Galata silty clay, 4-8%  
Hc - Haverson silt loam  
Hf - Haverson soils channeled  
Hk - Heldt silty clay loam, 2-4%  
Hm - Heldt silty clay loam, 4-8%  
Hn - Hesper silty clay loam, 0-2%  
Ho - Hesper silty clay loam, 2-4%  
Hp - Hesper silty clay loam, 4-8%  
Hr - Hesper silty clay loam, 8-15%  
Hs - Hapley - Relan loams, 4-8%  
Ht - Hydro silty clay loam, 0-2%  
Hu - Hydro silty clay loam, 2-4%  
Hv - Hydra silty clay loam, 4-8%

# SYMBOL SERIES/ASSOCIATION

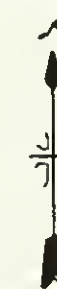
Hw - Hydro - Arvada complex, 2-8%  
Hx - Hydro - Elso, 8-15%  
Hy - Hydro - Fort Collins silt loams, 0-2%  
Km - Kyle clay, 4-8%  
Mc - McRae silt loam, 0-2%  
Md - McRae silt loam, 2-4%  
Mf - Midway silty clay loam, 2-8%  
Mg - Midway - Elso, 8-35%  
Mt - Midway - Thurlow, 8-15%  
Mw - Midway - Elso rocky soils, 35-75%  
Rc - Rapelje silt loam, 2-8%  
Rh - Relan - Cabba, 4-8%  
Rk - Relan gravelly loam, 4-8%  
Ro - Remmit - Ocean lake fine sandy loams, 8-25%  
Rs - Ringling slaty loam, 20-50%  
Rt - Ringling - Cabba, 15-50%  
Ru - Ringling - Relan, 6-25%  
Tm - Thurlow silty clay loam, 2-4%  
Ta - Thurlow silty clay loam, 4-8%  
Tr - Thurlow silty clay loam, 8-15%  
Vr - Vona - Remmit fine sandy loams, 4-8%



## NOTE

Information taken from "Soil Survey of the Powder River Area - Montana," Published by the USDA-SCS, 1971.

T. 3 S., R. 49 E.  
Sections 26, 28, 30, 32



UNITED STATES DEPARTMENT OF THE INTERIOR WATER AND POWER RESOURCES SERVICE	
RESOURCE & POTENTIAL RECLAMATION EVALUATION	
PUMPKIN CREEK STUDY AREA PUMPKIN CREEK COAL FIELD-MONTANA SOIL INVENTORY MAP	
LANDS G. WESTMAN	SUBMITTED
DRAWN L. E. ALLSOP	RECOMMENDED
CHECKED	APPROVED
BILLINGS, MONTANA	FEB., 1980
1305-600-242	



U.S. BUREAU OF RECLAMATION  
POINT SITE LAND CHARACTERIZATION  
(WITH DETERMINATIONS)

Study Area: Pumpkin Creek, Montana  
Location: Sec. 8 Twp. 38 Range 49E  
550' E., 450' S. of W<sub>1</sub> corner  
Climate: Semiarid  
Land Use: Range  
Point Site Number: 5

Relief: Simple, gently sloping  
Elevation: 3480  
Slope: Aspect: West; 4-8°  
Vegetation: Western wheatgrass, Green Needlegrass  
Erosion: Slight

Stoniness: None  
Drainage: Well  
Ground Water: None  
Land Form: Residual

Parent Material: Sandstone, Soft shale  
Soil Series: Kober  
Soil Classification: Fine, montmorillonitic  
Borallie Camborthids  
Profile Description: By: T. Flecht Date: 11/76  
Correlated By: M. Volk Date: 7/79

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION	DETERMINATION		LABORATORY DESCRIPTION									
			LABORATORY NUMBER	DEPTH (ft)	PARTICLE SIZE ANALYSIS (percent)	TEXTURAL CLASS (LAB)	BULK DENSITY (g/cm <sup>3</sup> )	HYDRAULIC CONDUCTIVITY (in/hr)	SETTLING VOLUME (ml)	MOISTURE RETENTION (percent)	SOIL REACTION-pH	ORGANIC CARBON (percent)	AVAILABLE PHOSPHORUS (ppm)	CO <sub>2</sub> EQUIVALENT (percent)
T 2098 Bis-5422	0-12"	A1 0-6 inches, pale brown (10YR 6/3) silty clay loam, dark grayish brown (10YR 4/2) moist; weak, medium, blocky structure; separating to weak, medium crumb structure; soft dry, very friable moist, sticky, slightly plastic wet; abundant fine roots; noncalcareous; gradual boundary.	5422 0.0-1.0	5423 1.0-2.0	5424 2.0-3.5	5425 3.5-5.5	5426 5.5-7.0	5427 7.0-8.5	5428 8.5-10.0					
			Very Coarse Sand (2.0-1.0 mm)											
			Coarse Sand (1.0-0.5 mm)											
			Medium Sand (0.5-0.25 mm)											
			Fine Sand (0.25-0.10 mm)											
			Very Fine Sand (0.10-0.05 mm)											
			Total Sand (2.0-0.002 mm)											
			Silt (0.05-0.002 mm)											
			Clay (<0.002 mm)											
			TEXTURAL CLASS (LAB)											
			BULK DENSITY (g/cm <sup>3</sup> )											
			HYDRAULIC CONDUCTIVITY (in/hr)											
			6 in/hr											
			24 hr											
			SETTLING VOLUME (ml)											
			MOISTURE RETENTION (percent)											
			1/10 bar											
			1/3 bar											
			15 bar											
			SOIL REACTION-pH											
			Paste											
			1:5 H <sub>2</sub> O											
			1:2 0.01M CoCl <sub>2</sub>											
			ORGANIC CARBON (percent)											
			AVAILABLE PHOSPHORUS (ppm)											
			CO <sub>2</sub> EQUIVALENT (percent)											
			GYPSUM REQUIREMENT (me/100g)											
			SATURATION EXTRACT Saturation Percentage											
			EC <sub>e</sub> @25°C											
			Co++											
			Mg++											
			Na+											
			CO <sub>3</sub> -											
			HCO <sub>3</sub> -											
			Cl-											
			SO <sub>4</sub> -											
			NO <sub>3</sub> -											
			SAR											
			No											
			Co+Mg											
			1:5 EXTRACT											
			EC <sub>5</sub> @25°C											
			Co+Mg											
			EXCHANGEABLE SODIUM ACIDITY											
			IN KCl exchange acidity											
			Total											
			Al+++											
			CATION EXCHANGE CAPACITY											
			NaOAc@pH 8.2											
			BORON											
			(mg/l)											

\*Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.



U.S. BUREAU OF RECLAMATION  
POINT SITE LAND CHARACTERIZATION  
(WITH DETERMINATIONS)

Study Area: Pumpkin Creek, Montana Relief: Complex, undulating Stoniness: None Parent Material: Sandstone, soft shales  
Location, Sec. 24 Twp. 2S Range 49E Elevation: 3620 Slope: Aspect: West; 2-4% Drainage: Well Soil Series: Delpoint  
200' N., 50' W. of E. corner Vegetation: Slender wheatgrass, Western wheatgrass Ground Water: None Soil Classification: Fine-loamy, mixed  
Climate: Semiarid Erosion: Slight Land Form: Residual Borrolitic Camborthids  
Land Use: Range  
Point Site Number: 11 Profile Description By: T. Fiechtl Date: 11/76  
Correlated By: W. Volk Date: 7/79

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION	LABORATORY DESCRIPTION	
			DETERMINATION	DATA
T 2079 Bis-5403	0-12"	A <sub>1</sub> 0-2 inches, brown (10YR 5/3) silt loam, dark brown (10YR 5/3) moist; weak, medium, blocky structure separating to weak, fine, blocky structure; slightly hard dry, friable moist, slightly sticky, nonplastic wet; plentiful fine roots; noncalcareous; gradual boundary.	LABORATORY NUMBER	S403 S404 S405 S406 S407 S408
		B <sub>2</sub> 2-12 inches, brown (10YR 4/3) silt loam, dark brown (10YR 5/3) moist; weak, medium, prismatic structure, breaking to weak, medium, blocky structure; slightly hard dry; very friable moist, sticky, slightly plastic wet; plentiful fine roots; slight calcareous; gradual boundary.	DEPTH (ft.)	0.0-1.0 1.0-2.5 2.5-4.0 4.0-6.0 6.0-8.0 8.0-10.0
		B <sub>3ca</sub> 12-30 inches, yellowish brown (10YR 5/4) silt loam, brown (10YR 4/3) moist; weak, medium, prismatic structure, breaking to weak, medium, blocky structure; slightly hard dry, friable moist, sticky, slightly plastic wet; plentiful fine roots; violently calcareous; abrupt boundary.	PARTICLE SIZE ANALYSIS (percent)	
		C <sub>cs</sub> 15-30 inches, very pale brown (10YR 8/3) silt loam, very pale brown (10YR 7/3) moist; weak, coarse, blocky structure, breaks to weak, medium, blocky structure; hard dry, very friable moist, sticky, slightly plastic wet; few fine roots; strongly calcareous; abrupt boundary.	Very Coarse Sand (2.0-1.0mm)	
		C <sub>2</sub> 30-48 inches, very pale brown (10YR 7/3) silt loam, light brownish gray (10YR 6/2) moist; massive to weak, very coarse, blocky structure; hard dry, friable moist, slightly sticky, slightly plastic wet; few fine roots; strongly calcareous; abrupt boundary.	Coarse Sand (1.0-0.5mm)	
T 2081 Bis-5405	30-48"	C <sub>3</sub> 48-72 inches, very pale brown (10YR 7/4) silt loam, pale brown (10YR 6/3) moist; massive structure; hard dry, friable moist, slightly sticky and slightly plastic wet; slightly calcareous; abrupt boundary.	Medium Sand (0.5-0.25mm)	
		C <sub>4</sub> 72-96 inches, light yellowish brown (10YR 6/4) silt loam, yellowish brown (10YR 5/6) moist; massive structure; hard dry, friable moist, slightly sticky, slightly plastic wet, slightly calcareous; abrupt boundary.	Fine Sand (0.25-0.10mm)	
		C <sub>5</sub> 96-120 inches, light yellowish brown (10YR 6/4) loam, yellowish brown (10YR 5/6) moist; massive structure; hard dry, friable moist, nonsticky, slightly plastic wet; slightly calcareous.	Very Fine Sand (0.10-0.05mm)	
			Silt (0.05-0.002mm)	
			Clay (<0.002mm)	
T 2082 Bis-5406	48-72"		TEXTURAL CLASS (LAB)	
			BULK DENSITY (g/cm <sup>3</sup> )	
			HYDRAULIC CONDUCTIVITY (in/hr)	
			SEITTLING VOLUME (ml)	
			MOISTURE RETENTION (percent)	
T 2083 Bis-5407	72-96"		SOIL REACTION-pH	
			Paste	
			1:5 H <sub>2</sub> O	
			1:2 0.01M CaCl <sub>2</sub>	
			ORGANIC CARBON (percent)	
T 2084 Bis-5408	96-120"		AVAILABLE PHOSPHORUS (ppm)	
			CaCO <sub>3</sub> EQUIVALENT (percent)	
			GYPSUM REQUIREMENT (me/100g)	
			SATURATION EXTRACT	
			Saturation Percentage EC <sub>e</sub> @ 25°C	
			Ca++	
			Mg++	
			Na+	
			K+	
			CO <sub>3</sub> <sup>-</sup>	
			HCO <sub>3</sub> <sup>-</sup>	
			Cl-	
			SO <sub>4</sub> <sup>-</sup>	
			NO <sub>3</sub> <sup>-</sup>	
			SAR	
			Na	
			Co+Mg	
			1:5 EXTRACT	
			EC <sub>s</sub> @ 25°C	
			Ca+Mg	
			EXCHANGEABLE SODIUM	
			ACIDITY	
			IN KCl exchange acidity	
			Total	
			Al+++	
			CATION EXCHANGE CAPACITY (me/100g)	
			NaOAc@pH 8.2	
			BORON (mg/l)	



U.S. BUREAU OF RECLAMATION  
POINT SITE LAND CHARACTERIZATION  
(WITH DETERMINATIONS)

Study Area: Pumpkin Creek, Montana  
Location: Sec. 20 Twp. 35 Range 49E  
750' S., 550' E. of NW corner  
Climate: Semiarid  
Land Use: Range  
Point Site Number: 1

Relief: Simple, moderately sloping  
Elevation: 3480  
Slope: Aspect: East; 6-8%  
Vegetation: Blue Grama grass, Needle and Thread  
Fescue, Three-Aw Sedge  
Erosion: Slight

Stoniness: None  
Drainage: Well  
Ground Water: None  
Land Form: Residual side slope

Parent Material: Sandstone, Soft shales  
Soil Series: Yamoc  
Soil Classification: Fine-loamy, mixed  
Borollie Camborthids  
Profile Description By: T. Fiechl Date: 11/76  
Correlated By: J. L. K Date: 7/79

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION	LABORATORY DESCRIPTION	
			DETERMINATION	DATA
T 2111 Bis-5435	0-12"	A <sub>1</sub> 0-1 inch, pale brown (10YR 6/3) silt loam, brown (10YR 5/3) moist; weak, coarse, crumb structure, separates to weak, fine crumb structure; loose dry, very friable moist, nonsticky, nonplastic wet; plentiful fine roots; noncalcareous; abrupt boundary.	LABORATORY NUMBER	5435 5436 5437 5438 5440
		AB 1-5 inches, brown (10YR 5/3) clay loam, dark brown (10YR 4/3) moist; weak, medium, blocky structure, breaks to weak, fine, blocks; hard dry, friable moist, slightly sticky, slightly plastic wet; plentiful fine roots; noncalcareous; abrupt boundary.	DEPTH (ft)	0.0-1.0 1.0-2.5 2.5-4.0 4.0-6.0 6.0-8.0 8.0-10.0
		B <sub>2</sub> 5-9 inches, brown (10YR 5/3) clay loam, dark grayish brown (10YR 4/2) moist; moderate, medium, prismatic structure, breaks to moderate, medium, blocky structure; hard dry, friable moist, sticky, plastic wet; plentiful fine roots; noncalcareous; abrupt boundary.	PARTICLE SIZE ANALYSIS (percent)	
		B <sub>3</sub> 9-14 inches, pale brown (10YR 6/3) clay loam, brown (10YR 5/3) moist; weak, medium prismatic structure breaks to weak, medium, blocky structure; very hard dry, friable moist, sticky, plastic wet; plentiful fine roots; slightly calcareous; abrupt boundary.	Very Coarse Sand (2.0-1.0 mm)	
		C <sub>1Ca</sub> 14-30 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; weak, coarse, blocky structure, breaks to weak, medium, blocky structure, hard dry, friable moist, sticky, plastic wet; few fine roots; strongly calcareous; abrupt boundary.	Coarse Sand (1.0-0.5 mm)	
	12-30"	C <sub>2</sub> 30-48 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	Medium Sand (0.5-0.25 mm)	
		C <sub>3</sub> 48-72 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	Fine Sand (0.25-0.10 mm)	
		C <sub>4</sub> 72-96 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	Very Fine Sand (0.10-0.05 mm)	
		C <sub>5Cs</sub> 96-120 inches, pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; hard dry, friable moist, slightly sticky, slightly plastic wet; strongly calcareous; diffuse boundary.	Silt (<0.002 mm)	
		96+ inches-salt accumulation	Clay (<0.002 mm)	
T 2112 Bis-5436	30-48"	C <sub>1Ca</sub> 14-30 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; weak, coarse, blocky structure, breaks to weak, medium, blocky structure, hard dry, friable moist, sticky, plastic wet; few fine roots; strongly calcareous; abrupt boundary.	TEXTURAL CLASS (LAB)	CL CL CL CL CL
		C <sub>2</sub> 30-48 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	BULK DENSITY (g/cm <sup>3</sup> )	0.02 0.02 0.04 0.01 0.01
		C <sub>3</sub> 48-72 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	HYDRAULIC CONDUCTIVITY (in/hr)	0.02 0.02 0.02 0.01 0.01
		C <sub>4</sub> 72-96 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	SETTLING VOLUME (ml)	24 24 24 25 24
		C <sub>5Cs</sub> 96-120 inches, pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; hard dry, friable moist, slightly sticky, slightly plastic wet; strongly calcareous; diffuse boundary.	MOISTURE RETENTION (percent)	38.9 36.8 33.8 33.9 35.1
	48-72"	C <sub>1Ca</sub> 14-30 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; weak, coarse, blocky structure, breaks to weak, medium, blocky structure, hard dry, friable moist, sticky, plastic wet; few fine roots; strongly calcareous; abrupt boundary.	1/10 bar	32.0 30.6 30.8 32.3 24.5
		C <sub>2</sub> 30-48 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	1/3 bar	15.1 14.6 12.9 13.2 13.0
		C <sub>3</sub> 48-72 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	15 bar	8.1 8.4 8.8 9.0 8.4
		C <sub>4</sub> 72-96 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	SOIL REACTION-pH	7.3 7.7 8.0 8.0 8.2
		C <sub>5Cs</sub> 96-120 inches, pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; hard dry, friable moist, slightly sticky, slightly plastic wet; strongly calcareous; diffuse boundary.	Poste	-0.9 -0.4 +0.2 +0.8 -4.4
T 2113 Bis-5437	30-48"	C <sub>1Ca</sub> 14-30 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; weak, coarse, blocky structure, breaks to weak, medium, blocky structure, hard dry, friable moist, sticky, plastic wet; few fine roots; strongly calcareous; abrupt boundary.	1:5 H <sub>2</sub> O	0.70 0.88 0.66 0.66 0.60
		C <sub>2</sub> 30-48 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	1:2 0.01 M CoCl <sub>2</sub>	2.14 2.14 3.62 3.08 45.81
		C <sub>3</sub> 48-72 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	ORGANIC CARBON (percent)	5.88 3.89 3.62 3.08 45.81
		C <sub>4</sub> 72-96 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	AVAILABLE PHOSPHORUS (ppm)	1.91 1.91 4.50 10.65 30.60
		C <sub>5Cs</sub> 96-120 inches, pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; hard dry, friable moist, slightly sticky, slightly plastic wet; strongly calcareous; diffuse boundary.	CoCO <sub>3</sub> EQUIVALENT (percent)	0.53 0.23 0.21 0.29 0.90
	48-72"	C <sub>1Ca</sub> 14-30 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; weak, coarse, blocky structure, breaks to weak, medium, blocky structure, hard dry, friable moist, sticky, plastic wet; few fine roots; strongly calcareous; abrupt boundary.	GYPSUM REQUIREMENT (me/100g)	0.00 0.08 0.32 0.40 0.00
		C <sub>2</sub> 30-48 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	SATURATION EXTRACT (me/100g)	9.68 4.56 5.08 5.00 1.80
		C <sub>3</sub> 48-72 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	Saturation Percentage	0.94 0.92 1.14 2.62 5.36
		C <sub>4</sub> 72-96 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	EC <sub>e</sub> @ 25°C	2.56 0.88 1.50 5.41 96.40
		C <sub>5Cs</sub> 96-120 inches, pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; hard dry, friable moist, slightly sticky, slightly plastic wet; strongly calcareous; diffuse boundary.	Co++	0.02 0.02 0.19 0.05 0.17
T 2114 Bis-5438	72-96"	C <sub>1Ca</sub> 14-30 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; weak, coarse, blocky structure, breaks to weak, medium, blocky structure, hard dry, friable moist, sticky, plastic wet; few fine roots; strongly calcareous; abrupt boundary.	Co+	0.7 3.1 7.8 5.1 5.8
		C <sub>2</sub> 30-48 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	Na	0.33 0.38 0.75 1.33 1.07
		C <sub>3</sub> 48-72 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	Co+Mg	0.24 0.24 0.24 0.32 1.70
		C <sub>4</sub> 72-96 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	1:5 EXTRACT	1.8 2.2 5.1 9.1 6.4
		C <sub>5Cs</sub> 96-120 inches, pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; hard dry, friable moist, slightly sticky, slightly plastic wet; strongly calcareous; diffuse boundary.	EC <sub>5</sub> @ 25°C	17.0 14.8 14.6 14.1
	96-120"	C <sub>1Ca</sub> 14-30 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; weak, coarse, blocky structure, breaks to weak, medium, blocky structure, hard dry, friable moist, sticky, plastic wet; few fine roots; strongly calcareous; abrupt boundary.	Co+Mg	0.26 0.24 0.24 0.32 1.70
		C <sub>2</sub> 30-48 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	EXCHANGEABLE SODIUM (percent)	1.8 2.2 5.1 9.1 6.4
		C <sub>3</sub> 48-72 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	IN KCl exchange acidity Total	17.0 14.8 14.6 14.1
		C <sub>4</sub> 72-96 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.	CATION EXCHANGE CAPACITY (me/100g)	18.8 17.0 14.8 14.6 14.1
		C <sub>5Cs</sub> 96-120 inches, pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; hard dry, friable moist, slightly sticky, slightly plastic wet; strongly calcareous; diffuse boundary.	NaOAc@pH 8.2	16.6 16.6 16.6 14.1
T 2115 Bis-5439	72-96"	C <sub>1Ca</sub> 14-30 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; weak, coarse, blocky structure, breaks to weak, medium, blocky structure, hard dry, friable moist, sticky, plastic wet; few fine roots; strongly calcareous; abrupt boundary.	BORON (mg/l)	14.1 14.1 14.1 14.1 14.1
		C <sub>2</sub> 30-48 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.		
		C <sub>3</sub> 48-72 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.		
		C <sub>4</sub> 72-96 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.		
		C <sub>5Cs</sub> 96-120 inches, pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; hard dry, friable moist, slightly sticky, slightly plastic wet; strongly calcareous; diffuse boundary.		
	96-120"	C <sub>1Ca</sub> 14-30 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; weak, coarse, blocky structure, breaks to weak, medium, blocky structure, hard dry, friable moist, sticky, plastic wet; few fine roots; strongly calcareous; abrupt boundary.		
		C <sub>2</sub> 30-48 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.		
		C <sub>3</sub> 48-72 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.		
		C <sub>4</sub> 72-96 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.		
		C <sub>5Cs</sub> 96-120 inches, pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; hard dry, friable moist, slightly sticky, slightly plastic wet; strongly calcareous; diffuse boundary.		
T 2116 Bis-5440	96-120"	C <sub>1Ca</sub> 14-30 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; weak, coarse, blocky structure, breaks to weak, medium, blocky structure, hard dry, friable moist, sticky, plastic wet; few fine roots; strongly calcareous; abrupt boundary.		
		C <sub>2</sub> 30-48 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.		
		C <sub>3</sub> 48-72 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.		
		C <sub>4</sub> 72-96 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.		
		C <sub>5Cs</sub> 96-120 inches, pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; hard dry, friable moist, slightly sticky, slightly plastic wet; strongly calcareous; diffuse boundary.		
	96-120"	C <sub>1Ca</sub> 14-30 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; weak, coarse, blocky structure, breaks to weak, medium, blocky structure, hard dry, friable moist, sticky, plastic wet; few fine roots; strongly calcareous; abrupt boundary.		
		C <sub>2</sub> 30-48 inches, very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.		
		C <sub>3</sub> 48-72 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.		
		C <sub>4</sub> 72-96 inches, light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.		
		C <sub>5Cs</sub> 96-120 inches, pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; hard dry, friable moist, slightly sticky, slightly plastic wet; strongly calcareous; diffuse boundary.		



Study Area: Pumpkin Creek, Montana			Relief: Simple, gently to moderately sloping			Stoniness: None			Parent Material: Sandstone, Soft shale		
Location. Sec. 26 Twp. 35 Range 49E			Elevation: 3480			Slope: Aspect: West; 2-6%			Soil Series: Archin		
450' W. of N.E. corner			Vegetation: Western wheatgrass, Blue Gramma grass, forbs			Drainage: Well			Soil Classification: Fine-loamy, mixed		
Climate: Semiarid			Erosion: slight			Ground Water: None			Soil Classification: Borallitic Natrargids		
Land Use: Range			Erosion: slight			Land Form: Residual side slope			Profile Description: By T. Fiechl Date: 11/76		
Point Site Number: 1			Erosion: slight			Land Form: Residual side slope			Correlated By: W. Volk Date: 7/79		
LAB AND FIELD NO.		PROFILE DESCRIPTION		DETERMINATION		LABORATORY DESCRIPTION		DATA			
T 2117 Bis-5441	0-18"	A <sub>2</sub>	0-4 inches, light gray (10YR 7/2) silt loam, pale brown (10YR 6/3) moist; weak, medium, platy structure breaks to weak, medium crumb structure; slightly hard dry, loose moist, sticky, nonplastic wet; abundant fine roots; noncalcareous; abrupt boundary.	LABORATORY NUMBER	5441	5442	5443	5444	5445	5446	
				DEPTH (ft.)	0.0-1.5	1.5-3.0	3.0-4.5	4.5-6.0	6.0-8.0	8.0-10.0	
AB			4-6 inches, pale brown (10YR 6/3) clay loam, brown (10YR 4/3) moist; moderate, medium blocky structure, breaks to weak, fine, blocky structure; slightly hard dry, friable moist, sticky, slightly plastic wet; abundant fine roots; noncalcareous; gradual boundary.	PARTICLE SIZE ANALYSIS (percent)							
				(percent)							
B <sub>12</sub>			6-10 inches, pale brown (10YR 6/3) clay loam, dark grayish brown (10YR 4/3) moist; moderate, medium, prismatic structure, breaks to moderate, fine, blocky structure; hard dry, friable moist, sticky, plastic wet; plastic wet; plentiful fine roots; slightly calcareous; gradual boundary.	TEXTURAL CLASS (LAB)							
				(LAB)							
B <sub>22</sub>			10-18 inches, pale brown (10YR 6/3) clay loam, yellowish brown (10YR 5/4) moist; weak, medium, columnar prisms, breaks to moderate, medium blocky structure; hard dry, friable moist, sticky, plastic wet; plentiful fine roots; strongly calcareous; gradual boundary.	BULK DENSITY (g/cm <sup>3</sup> )							
				(in/hr)							
C <sub>1cs</sub>	18-36"		18-36 inches, pale brown (10YR 6/3) moist; weak coarse blocky structure, breaks to weak, medium, blocky structure; hard dry, very friable moist; very sticky, plastic wet; few fine roots; strongly calcareous; gradual boundary.	HYDRAULIC CONDUCTIVITY							
				6 hr							
C <sub>2</sub>	36-54"		36-54 inches, very pale brown (10YR 7/3) heavy clay loam, pale brown (10YR 6/3) moist; massive structure; hard dry, friable moist, sticky, plastic wet; slightly calcareous; abrupt boundary.	SETTLING VOLUME							
				(ml)							
C <sub>3cs</sub>	54-72"		54-72 inches, very pale brown (10YR 7/3) heavy clay loam, very friable moist, sticky, plastic wet; slightly calcareous; diffuse boundary.	MOISTURE RETENTION (percent)							
				(percent)							
T 2121 Bis-5445	72-96"		72-96 inches, very pale brown (10YR 7/3) light clay loam, pale brown (10YR 6/3) moist; massive structure; hard dry, very friable, sticky, slightly plastic wet; slightly calcareous; diffuse boundary.	SOIL REACTION - pH							
				Paste							
T 2122 Bis-5446	96-120"		96-120 inches, very pale brown (10YR 7/3) light clay loam, pale brown (10YR 6/3) moist; massive structure; hard dry, very friable, sticky, slightly plastic wet; slight calcareous; diffuse boundary.	1:5 H <sub>2</sub> O							
				1:2 0.01M CaCl <sub>2</sub>							
				ORGANIC CARBON (percent)							
				AVAILABLE PHOSPHORUS (ppm)							
				CaCO <sub>3</sub> EQUIVALENT (percent)							
				GYPSUM REQUIREMENT (me/100g)							
				SATURATION EXTRACT							
				Saturation Percentage							
				EC <sub>e</sub> @ 25°C (mmhos/cm)							
				Ca++ (me/l)							
				Mg++ (me/l)							
				Na+ (me/l)							
				K+ (me/l)							
				CO <sub>3</sub> - (me/l)							
				HCO <sub>3</sub> - (me/l)							
				Cl- (me/l)							
				SO <sub>4</sub> - (me/l)							
				NO <sub>3</sub> - (me/l)							
				SAR (me/l)							
				Na (me/100g)							
				Ca+Mg (me/100g)							
				I:5 EXTRACT							
				EC <sub>5</sub> @ 25°C (me/100g)							
				Ca+Mg (me/100g)							
				EXCHANGEABLE SODIUM							
				ACIDITY							
				IN KCl exchange acidity							
				Total (me/100g)							
				Al+++ (me/100g)							
				CATION EXCHANGE CAPACITY (me/100g)							
				NaOAc@pH 8.2 (me/100g)							
				BORON (mg/l)							



U.S. BUREAU OF RECLAMATION  
POINT SITE LAND CHARACTERIZATION  
(WITH DETERMINATIONS)

Study Area: Pumpkin Creek, Montana  
Location, Sec. 32, Twp. 35, Range 49E  
800' E., 450' N. of W<sub>3</sub> corner  
Climate: Semiarid  
Land Use: Range  
Point Site Number: 1

Relief: Simple, gently to moderately sloping  
Elevation: 3635  
Slope: Aspect: East, 4-6%  
Vegetation: Blue Gramma grass, Green Needlegrass, Three Ann Sedge  
Erosion: Slight to Severe

Stoniness: None  
Drainage: Well  
Ground Water: None  
Land Form: Residual side slope

Parent Material: Soft Shale  
Soil Series: Cabbert, sodic phase  
Soil Classification: Loamy, mixed (calcareous),  
frigid, shallow, ustic Torriorthents  
Profile Description By: T. Flecht Date: 11/76  
Correlated By: W. Volk Date: 7/79

LAB AND FIELD NO.			DEPTH (Inches)	PROFILE DESCRIPTION	LABORATORY DESCRIPTION									
					DETERMINATION		DATA							
T 2105 Bis-5429	0-18"	A <sub>1</sub>	0-1 inch, light brownish gray (10YR 6/2) silt loam, brown (10YR 5/3) moist; weak, medium, crumb structure, separates to weak, fine, crumb structure; loose dry, loose moist, sticky, nonplastic; plentiful fine roots; slightly calcareous; abrupt boundary.	LABORATORY NUMBER	5429	5430	5431	5432	5433	5434				
				DEPTH (ft)	0.0-1.5	1.5-2.5	2.5-4.0	4.0-6.0	6.0-8.0	8.0-10.0				
				PARTICLE SIZE ANALYSIS (percent)										
				Very Coarse Sand (2.0-1.0mm)										
				Coarse Sand (1.0-0.5mm)										
C <sub>1</sub>	1-5 inches, brown (10YR 5/3) clay loam, dark brown (10YR 4/3) moist; moderate, medium, blocky structure, breaks to moderate, fine, blocky structure; slightly hard dry, friable moist, sticky, slightly plastic; plentiful fine roots; strongly calcareous; abrupt boundary.	Medium Sand (0.5-0.25mm)												
		Fine Sand (0.25-0.10mm)												
		Very Fine Sand (0.10-0.05mm)												
		Total Sand (2.0-0.05mm)												
		Silt (0.05-0.002mm)												
C <sub>2ca</sub>	5-18 inches, pale brown (10YR 6/3) clay loam, brown (10YR 5/3) moist; weak, coarse, blocky structure, breaks to weak, medium, blocky; hard dry, very friable moist; sticky, plastic wet; few fine roots; strongly calcareous; abrupt boundary.	CLAY												
		TEXTURAL CLASS (LAB)												
		BULK DENSITY (g/cm <sup>3</sup> )												
		HYDRAULIC CONDUCTIVITY (in/hr)												
		6 <sup>in</sup> hr												
T 2106 Bis-5430	18-30"	C <sub>2cs</sub>	18-30 inches, very pale brown (10YR 7/3) loam, oale brown (10YR 6/3) moist; massive structure; hard dry, friable moist, slightly aticky, alightly plaatic wet; strongly calcareous; abrupt boundary.	24 <sup>th</sup> hr										
				SETTLING VOLUME (ml)										
				MOISTURE RETENTION (percent)										
				1/10 bar										
				1/3 bar										
T 2107 Bis-5431	30-48"	C <sub>2</sub>	30-48 inches, very pale brown (10YR 7/3) silt loam, pale brown (10YR 6/3) moist; masaiive structure; hard dry, friable maiait, sticky, nonplastic wet; strongly cal-careous; abrupt boundary.	SOIL REACTION-pH										
				Paste										
				1:5 H <sub>2</sub> O										
				1:2 0.01 M CaCl <sub>2</sub>										
				ORGANIC CARBON (percent)										
T 2108 Bis-5432	48-72"	C <sub>2s</sub>	48-72 inches, light yellowish brown (10YR 6/4) silty clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky, plaatic wet; strongly calcareous; abrupt boundary.	AVAILABLE PHOSPHORUS (ppm)										
				CaCO <sub>3</sub> EQUIVALENT (percent)										
				GYP SUM REQUIREMENT (me/100g)										
				SATURATION EXTRACTION (mmhos/cm)										
				EC <sub>e</sub> @ 25°C										
T 2109 Bis-5433	72-96"	C <sub>2c</sub>	72-96 inches, very pale brown (10YR 7/3) silty clay loam, pale brown (10YR 6/3) moist; mottling color varies dark gray (10YR 4/1) to light gray (10YR 6/1); masaiive structure; hard dry, friable moist, aticky, plastic wet; strongly calcareous, abrupt boundary.	Co++										
				Mg++										
				Na+										
				K+										
				CO <sub>3</sub> <sup>-</sup>										
T 2110 Bis-5434	96-120"	C <sub>2s</sub>	96-120 inches, very pale brown (10YR 7/4) silty clay loam, yellowish brown (10YR 5/4) moist; masaiive structure; hard dry, friable moist, aticky, plastic wet; atrongly calcareous.	HCO <sub>3</sub> <sup>-</sup>										
				Cl-										
				SO <sub>4</sub> <sup>-</sup>										
				NO <sub>3</sub> <sup>-</sup>										
				SAR										
T 2111 Bis-5434	18+-inches-salt accumulation 18+-inches-stratified oxidized and ferroua shales	C <sub>2s</sub>		Na										
				Co+Mg										
				1:5 EXTRACTION										
				EC <sub>s</sub> @ 25°C										
				Co+Mg										
T 2112 Bis-5434		C <sub>2s</sub>		EXCHANGEABLE SODIUM ACIDITY										
				IN KCl exchange acidity										
				Total										
				Al+++										
				CATION EXCHANGE CAPACITY NaOAc@pH 8.2										
T 2113 Bis-5434		BORON		NaOAc@pH 8.2										
				(mg/l)										
				18+-inches-salt accumulation										
				18+-inches-stratified oxidized and ferroua shales										

\*Denotes that no water was transmitted through soil column prior to or during the specified testing period; GPO 833.796

Fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.



U.S. BUREAU OF RECLAMATION  
POINT SITE LAND CHARACTERIZATION  
(WITH DETERMINATIONS)

Study Area: Pumpkin Creek, Montana  
Location: Sec. 28 Twp. 3S Range 49E  
700' S., 200' E. of NW corner  
Climate: Semiarid  
Land Use: Range  
Point Site Number: 1

Relief: Complex, undulating  
Elevation: 3580  
Slope: Aspect: South; 2-4%  
Vegetation: Western wheatgrass, Blue Gramma grass,  
Erasian: Slight

Stoniness: None  
Drainage: Well  
Ground Water: None  
Land Form: Colluvial foot slope over soft shale

Parent Material: Sandstone, soft shale  
Soil Series: Creed  
Soil Classification: Fine, montmorillonitic  
Borollitic Natragids

Profile Description By: T. Flecht Date: 11/76  
Correlated By: W. Volk Date: 7/79

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION	LABORATORY DESCRIPTION		DETERMINATION		DATA	
			LABORATORY NUMBER	DEPTH (ft.)	LABORATORY NUMBER	DEPTH (ft.)	LABORATORY NUMBER	DEPTH (ft.)
T 2123 Bis-5447	0-12"	0-4 inches, pale brown (10YR 6/3) clay loam, brown (10YR 5/3) moist; weak, medium, blocky structure, breaks to weak, fine, blocky structure; slightly hard dry, friable moist, slightly sticky, slightly plastic wet; abundant fine roots; noncalcareous; abrupt boundary.	Very Coarse Sand (2.0-1.0mm)	5447	5448	5449	5450	5451
			Coarse Sand (1.0-0.5mm)	0.0-1.0	1.0-2.5	2.5-4.0	4.0-5.5	5.5-7.5
			Medium Sand (0.5-0.25mm)					
			Fine Sand (0.25-0.10mm)					
			Very Fine Sand (0.10-0.05mm)					
T 2124 Bis-5448	12-30"	4-9 inches, pale brown (10YR 6/3) heavy clay loam, brown (10YR 5/3) moist; weak, medium, prismatic structure, breaks to moderate, fine, blocky structure; hard dry, friable moist, sticky, plastic wet; many thin clay films on ped faces; abundant fine roots; slightly calcareous; gradual boundary.	Total Sand (2.0-0.05mm)	25.0	18.0	53.1	70.9	11.0
			Silt (0.05-0.002mm)	36.4	45.5	30.6	15.9	77.5
			Clay (<0.002mm)	38.6	36.5	16.3	13.2	11.5
			TEXTURAL CLASS (LAB)	CL	SACL	VFSL	FSL	CL
			DENSITY (g/cm <sup>3</sup> )					
T 2125 Bis-5449	30-48"	9-15 inches, pale brown (10YR 6/3) silty clay loam, brown (10YR 5/3) moist; moderate, medium, prismatic structure, breaks to moderate, fine, medium blocky structure; hard dry, friable moist, sticky, plastic wet; many thin clay films on ped faces; plentiful fine roots; strongly calcareous; gradual boundary.	HYDRAULIC CONDUCTIVITY (in/hr)	0.02	*4/5	0.08	0.39	0.43
			6" hr	0.04	*	0.06	0.39	0.55
			24" hr	26	39	25	24	21
			SETTLING VOLUME (ml)					
			MOISTURE RETENTION (percent)					
T 2126 Bis-5450	48-66"	15-30 inches, very pale brown (10YR 7/3) silty clay loam, brown (10YR 6/3) moist; moderate, medium, prismatic structure, breaks to moderate, medium, blocky structure; very hard dry, friable moist, very sticky, plastic wet; few fine roots; strongly calcareous; gradual boundary.	1/10 bar	39.9	41.8	34.9	27.0	22.3
			1/3 bar	28.5	29.8	22.3	15.7	13.7
			15 bar	16.2	17.2	7.9	6.6	5.3
			SOIL REACTION-pH					
			1:5 H <sub>2</sub> O	8.4	9.0	9.0	8.8	8.0
T 2127 Bis-5451	66-90"	30-48 inches, light gray (10YR 7/2) heavy very fine sandy loam, pale brown (10YR 6/3) moist; massive structure; slightly hard dry, very friable moist, slightly sticky, slightly plastic wet; noncalcareous; abrupt boundary.	1:2 0.01 M CoCl <sub>2</sub>	7.7	7.8	7.8	7.9	7.8
			ORGANIC CARBON (percent)					
			AVAILABLE PHOSPHORUS (ppm)					
			CoCl <sub>3</sub> EQUIVALENT (percent)					
			GYP SUM REQUIREMENT (me/100g)					
T 2128 Bis-5452	90-102"	48-66 inches, white (10YR 8/1) fine sandy loam, light gray (10YR 7/2) moist; massive structure; slightly hard dry, loose moist, nonsticky, nonplastic wet; noncalcareous; diffuse boundary.	SATURATION EXTRACT Solution Percentages EC <sub>e</sub> @ 25°C	1.3	2.7	5.5	7.0	6.0
			Co++	4.72	2.69	12.03	21.91	18.56
			Mg++	7.80	2.44	10.77	21.55	13.67
			Na+	5.40	24.00	43.87	53.13	40.65
			K+	0.23	0.13	0.34	0.42	0.31
T 2129 Bis-5453	102-120"	66-90 inches, same as 48-66 inch description 90-102 inches, light gray (10YR 7/2) light clay loam, pale brown (10YR 6/3) moist, mottling varies from brownish yellow (10YR 6/6) to a brown (7.5YR 5/3) moist; massive structure; very hard dry, extremely firm moist; noncalcareous; abrupt boundary. 102-120 inches, gray (10YR 6/1) light silty clay, dark gray (10YR 4/1) moist, mottling colors same as 90-102 inch horizon; massive structure; very hard dry, extremely firm moist, sticky, plastic wet; noncalcareous. -Oxidized sandy shales at 30 inches. -Consolidated clayey shales at 90 inches. -Carbonaceous influence at 102 inches.	CO <sub>3</sub> - (me/l)	0.16	0.16	0.16	0.00	0.00
			HCO <sub>3</sub> - (me/l)	6.36	4.72	2.92	2.32	2.16
			Cl- (me/l)	1.14	7.42	7.24	3.23	2.66
			SO <sub>4</sub> - (me/l)	1.75	17.91	55.07	89.11	68.50
			NO <sub>3</sub> - (me/l)	0.03	0.02	0.12	0.20	0.58
			SAR (me/l)	2.8	15.0	13.0	9.4	9.6
			Co+Mg (me/100g)	0.76	3.76	1.37	0.81	0.65
			EC <sub>e</sub> @ 25°C (me/100g)					
			EXCHANGEABLE SODIUM (me/l)	0.38	0.64	0.90	1.20	0.96
			ACIDITY (percent)	3.1	17.0	14.0	10.0	9.3
			IN KCl exchange acidity Total					
			Al+++ (me/100g)					
			CATION EXCHANGE CAPACITY (me/100g)	24.2	22.1	9.7	8.1	7.0
			NO <sub>3</sub> -at pH 8.2 (mg/l)					
			BORON (mg/l)					

\*Denotes that no water was transmitted through soil column prior to or during the specified testing period; GPO 833.796  
Fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.



U.S. BUREAU OF RECLAMATION  
POINT SITE LAND CHARACTERIZATION  
(WITH DETERMINATIONS)

Study Area: Pumpkin Creek, Montana      Relief: Simple, gently sloping      Stoniness: None      Parent Material: Sandstone, soft shale  
Location: Sec 34 Twp 2S Range 49E      Elevation: 3670      Slope Aspect: South; 2-4%      Drainage: Well      Soil Series: Eithridge  
1000' N., 650' W. of E<sub>4</sub> corner      Vegetation: Small #rain      Ground Water: None      Soil Classification: Fine, montmorillonitic  
Climate: Semi-arid      Erosion: Slight      Land Form: Colluvial      Profile Description: By T. Flechtl      Date: 11/76  
Land Use: Cultivated      Point Site Number: 13      Correlated By: M. Volk      Date: 7/79

LAB AND FIELD NO.		DEPTH (Inches)	PROFILE DESCRIPTION	DETERMINATION	LABORATORY DESCRIPTION										DATA		
				LABORATORY NUMBER	DEPTH (ft)												
T 2085 Bis-5409	0-18"	A <sub>p</sub>	0-6 inches, grayish brown (10YR 5/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; weak, medium, blocky structure breaks to weak, medium, crumb structure; very soft friable dry, loose moist, sticky, slightly plastic wet; plentiful fine roots; noncalcareous; abrupt boundary.	PARTICLE SIZE ANALYSIS (percent) (2.0-1.0mm) (1.0-0.5mm) (0.5-0.25mm) (0.25-0.10mm) (0.10-0.05mm) (2.0-0.05mm) (0.05-0.002mm) ( $<0.002$ mm)	Very Coarse Sand Medium Sand Fine Sand Very Fine Sand Total Sand Silt Clay TEXTURAL CLASS (LAB) BULK DENSITY (g/cm <sup>3</sup> ) HYDRAULIC CONDUCTIVITY (in/hr)	5409	5410	5411	5412	5413	5414						
						0.0-1.5	1.5-3.0	3.0-5.0	5.0-7.0	7.0-8.5	8.5-10.0						
T 2086 Bis-5410	18-36"	B <sub>2</sub> 2t	6-10 inches, brown (10YR 5/3) silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate, medium, blocky prismatic structure, breaks to moderate, medium, blocky structure; very hard dry, friable moist, sticky and plastic wet; many, thin clay films on ped faces; noncalcareous; gradual boundary.	SOIL REACTION-pH Paste 1:5 H <sub>2</sub> O 1:2 0.01M CaCl <sub>2</sub> ORGANIC CARBON (percent) AVAILABLE PHOSPHORUS COC <sub>3</sub> EQUIVALENT (ppm) GYPSUM REQUIREMENT (percent) SATURATION EXTRACT (me/100g) Saturation Percentage EC <sub>e</sub> @ 25°C (mmhos/cm) EC <sub>e</sub> @ 25°C (me/l) Ca <sup>++</sup> Mg <sup>++</sup> Na <sup>+</sup> K <sup>+</sup> CO <sub>3</sub> <sup>2-</sup> HCO <sub>3</sub> <sup>-</sup> Cl <sup>-</sup> SO <sub>4</sub> <sup>2-</sup> NO <sub>3</sub> <sup>-</sup> SAR Na Co-Mg EXTRACT EC <sub>5</sub> @ 25°C Co-Mg EXCHANGEABLE SODIUM ACIDITY IN KCl exchange acidity Total Al <sup>+++</sup> NaOAc@pH 8.2 BORON	5409	5410	5411	5412	5413	5414							
					0.01	0.01	*	*4/5	*2/3	0.20							
					26	29	31	29	28	34							
T 2087 Bis-5411	30-60"	C <sub>ca</sub>	18-36 inches, pale brown (10YR 6/3) silty clay, brown (10YR 5/3) moist; moderate, coarse blocky structure, breaks to moderate, medium, blocks; very hard dry, firm moist, very sticky, plastic wet; few fine roots; violently calcareous; gradual boundary.	CO <sub>3</sub> <sup>2-</sup> (me/1)	5409	5410	5411	5412	5413	5414							
					0.84	4.00	8.60	10.00	8.60	8.40							
					1.65	10.98	23.65	52.45	31.59	23.05							
					2.99	20.81	71.63	79.61	72.62	70.64							
					4.96	20.09	45.13	43.22	40.83	38.65							
T 2088 Bis-5412	60-84"	C <sub>3</sub>	60-84 inches, pale brown (10YR 6/3) silty clay, brown (10YR 5/3) moist; massive structure; hard dry, firm moist, sticky, plastic wet; violently calcareous; abrupt boundary.	CO <sub>3</sub> <sup>2-</sup> (me/1)	5409	5410	5411	5412	5413	5414							
					0.12	0.28	0.61	1.23	0.85	0.17							
					0.32	0.00	0.00	0.00	0.00	0.00							
					6.32	1.84	1.44	3.16	4.60	1.12							
					0.44	0.00	1.92	2.00	1.20	1.52							
T 2089 Bis-5413	84-102"	C <sub>4</sub>	84-102 inches, grayish brown (10YR 5/2) silty clay, very dark grayish brown (10YR 3/2) moist; massive structure; hard dry, firm moist, sticky, plastic wet; violently calcareous; abrupt boundary.	CO <sub>3</sub> <sup>2-</sup> (me/1)	5409	5410	5411	5412	5413	5414							
					1.21	48.09	133.25	161.98	130.96	128.67							
					0.02	0.02	1.19	2.10	1.48	1.61							
					3.3	5.0	6.5	5.3	5.7	5.6							
					0.65	1.31	1.35	1.20	1.50	0.19							
T 2090 Bis-5414	102-120"	C <sub>5</sub>	102-120 inches, very pale brown (10YR 7/4) silty clay, yellowish brown (10YR 5/6) clayey shales.	CO <sub>3</sub> <sup>2-</sup> (me/100g) (mmhos/cm) (me/l) Ca <sup>++</sup> Mg <sup>++</sup> Na <sup>+</sup> K <sup>+</sup> CO <sub>3</sub> <sup>2-</sup> HCO <sub>3</sub> <sup>-</sup> Cl <sup>-</sup> SO <sub>4</sub> <sup>2-</sup> NO <sub>3</sub> <sup>-</sup> SAR Na Co-Mg EXTRACT EC <sub>5</sub> @ 25°C Co-Mg EXCHANGEABLE SODIUM ACIDITY IN KCl exchange acidity Total Al <sup>+++</sup> NaOAc@pH 8.2 BORON	5409	5410	5411	5412	5413	5414							
					0.24	0.88	3.40	2.80	3.20	3.30							
					2.60	5.70	6.20	5.80	6.70	6.00							

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; gpd 833.786  
Fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.



U.S. BUREAU OF RECLAMATION  
POINT SITE LAND CHARACTERIZATION  
(WITH DETERMINATIONS)

Study Area: Pumpkin Creek, Montana  
Location. Sec. 14 Twp. 35 Range 49E  
1000' S., 450' W. of E<sub>1</sub> corner  
Climate: Semiarid  
Land Use: Cultivated  
Point Site Number: 1

Relief: Simple, gently sloping  
Elevation: 3420  
Slope: Aspect: East; 2-4%  
Vegetation: Small rain  
Erosion: Slight

Stoniness: None  
Drainage: Well  
Ground Water: None  
Land Form: Alluvial

Parent Material: Sandstone, soft shales  
Soil Series: Yamac  
Soil Classification: Fine-loamy, mixed  
Borolllic Camborthids

Profile Description By: T. Fiechl Date: 11/76  
Correlated By: W. Volk Date: 7/79

LAB AND DEPTH (Inches)		PROFILE DESCRIPTION		DETERMINATION		LABORATORY DESCRIPTION	
FIELD NO.	DEPTH	PROFILE DESCRIPTION		LABORATORY NUMBER	(ft)	DATA	
T 2091 81s-5415	0-12"	Ap	0-6 inches, pale brown (10YR 6/3) silt loam, brown (10YR 5/3) moist; weak, medium blocky structure, senarating to weak, medium, crumb structure; slightly hard dry, friable moist, sticky, nonplastic; plentiful fine roots; slightly calcareous.	PARTICLE SIZE ANALYSIS	(percent)		
				Very Coarse Sand	(2.0-1.0mm)		
				Coarse Sand	(1.0-0.5mm)		
				Medium Sand	(0.5-0.25mm)		
				Fine Sand	(0.25-0.10mm)		
T 2092 81s-5416	12-36"	B <sub>2</sub>	6-12 inches, pale brown (10YR 6/3) silt loam, brown (10YR 5/3) moist; weak, coarse, prismatic structure, breaks to weak, coarse, blocky structure; slightly hard dry, friable moist, very sticky, slightly plastic; plentiful fine roots; strongly calcareous; abrupt boundary.	Total Sand	(2.0-0.05mm)	19.8	9.3
				Silt	(0.05-0.002mm)	52.7	64.4
				Clay	( $<0.002$ mm)	27.5	26.3
				SiL	SiL	36.4	36.4
				SiCL	SiCL	38.0	38.0
T 2093 81s-5417	36-48"	C <sub>2</sub>	12-36 inches, very pale brown (10YR 7/4) silty clay loam, pale brown (10YR 6/3) moist; weak, coarse, blocky structure breaks to weak, medium blocks; slightly hard dry, friable moist, very sticky, plastic wet; few fine roots; violently calcareous; abrupt boundary.	TEXTURAL CLASS (LAB)			
				BULK DENSITY	(g/cm <sup>3</sup> )		
				HYDRAULIC CONDUCTIVITY	(in/hr)		
				6 hr		0.16	0.24
				24 hr		0.16	0.28
T 2094 81s-5418	48-60"	C <sub>3b</sub>	36-48 inches, very pale brown (10YR 7/3) silt loam, pale brown (10YR 6/3) moist; massive structure; slightly hard dry, friable moist, very sticky, slightly plastic wet; strongly calcareous; gradual boundary.	SETTLING VOLUME	(ml)	26	22
				MOISTURE RETENTION	(percent)	28	25
				1/10 bar		35.0	33.1
				1/3 bar		37.6	35.0
				15 bar		28.6	23.8
T 2095 81s-5419	60-78"	C <sub>4</sub>	48-60 inches, light brownish gray (10YR 6/2) clay loam, dark gray (10YR 4/1) moist; massive structure; slightly hard dry, friable moist, sticky, plastic wet; strongly calcareous; gradual boundary.	SOIL REACTION-pH		19.2	11.7
				Paste		20.6	31.5
				1:5 H <sub>2</sub> O		18.4	19.3
				1:2 OIL M CaCl <sub>2</sub>			
				ORGANIC CARBON	(percent)	8.1	8.3
T 2096 81s-5420	78-96"	C <sub>5</sub>	60-78 inches, light yellowish brown (10YR 6/4) silty clay loam, yellowish brown (10YR 5/4) moist; massive structure; slightly hard dry, friable moist, sticky, plastic wet; gradually boundary.	AVAILABLE PHOSPHORUS	(ppm)	7.5	7.6
				CoCO <sub>3</sub> EQUIVALENT	(percent)	8.1	8.3
				GYPSUM REQUIREMENT	(me/100g)	7.8	7.8
				SATURATION EXTRACT			
				Saturation Percentage	(mmhos/cm)	-0.2	-0.4
T 2097 81s-5421	96-120"	C <sub>6</sub>	78-96 inches, light brown (7.5YR 6/3) silty clay loam, brown (7.5YR 5/3) moist; slightly hard dry, friable moist, sticky, plastic wet; strongly calcareous.	EC <sub>e</sub> @ 25°C	(me/l)	-1.6	-3.6
				Ca++		3.70	4.60
				Mg++		3.70	4.60
				Na+		23.75	23.60
				K+		1.45	1.45
			78-120-inches-Baked shale fragments	CO <sub>3</sub> -	(me/l)	16.28	22.20
				HCO <sub>3</sub> -	(me/l)	12.83	19.39
				Cl-	(me/l)	0.17	0.40
				SO <sub>4</sub> -	(me/l)	0.00	0.00
				NO <sub>3</sub> -	(me/l)	1.60	1.40
				SAR	(me/l)	0.36	0.80
				Na	(me/l)	2.85	45.80
				Ca+Mg	(me/l)	1.77	59.96
				EC <sub>e</sub> @ 25°C	(me/l)	1.94	0.15
				Ca+Mg	(me/100g)	0.3	0.5
				EXCHANGEABLE SODIUM	(mmhos/cm)	0.32	0.31
				ACIDITY	(percent)	0.14	0.54
				IN KCl exchange acidity		0.14	0.92
				Total		2.1	2.1
				Al+++		3.1	3.1
				CATION EXCHANGE CAPACITY	(me/100g)	2.1	3.1
				NaOAc@pH 8.2		15.5	15.0
				BORON	(mg/l)	22.3	21.2
						19.6	18.3



U.S. BUREAU OF RECLAMATION  
POINT SITE LAND CHARACTERIZATION  
(WITH DETERMINATIONS)

Study Area: Pumpkin Creek, Montana  
Location: Sec. 18, Twp. 3S, Range 49E  
1400'E., 1300'S., of NW corner  
Climate: Semiarid  
Land Use: Hay  
Point Site Number: 1

Relief: Simple, nearly level  
Elevation: 3360  
Slope: Aspect: North, 0-2%  
Vegetation: Alfalfa, Western Wheatgrass, Sweet Clover  
Erosion: Slight

Stoniness: None  
Drainage: Well  
Ground Water: None  
Land Form: Alluvial bottom

Parent Material: Sandstone  
Soil Series: Yamac  
Soil Classification: Fine-loamy, mixed  
Borollitic Camborthida

Profile Description By: T. Flechtl Date: 11/76  
Correlated By: W. Volk Date: 7/79

LAB AND FIELD NO.			DEPTH (Inches)		PROFILE DESCRIPTION	DETERMINATION	LABORATORY DESCRIPTION										DATA
T 2130 Bis-5454			0-12"		A <sub>1</sub>	0-1 inch, pale brown (10YR 6/3) silt loam, brown (10YR 5/3) moist; weak, medium, crumb structure, breaks to weak, fine, crumb structure; loose dry, loose moist nonsticky, nonplastic wet; plentiful fine roots; noncalcareous; abrupt boundary.	PARTICLE SIZE ANALYSIS (percent) (2.0-1.0mm) Very Coarse Sand (1.0-0.5mm) Coarse Sand (0.5-0.25mm) Medium Sand (0.25-0.10mm) Fine Sand (0.10-0.05mm) Very Fine Sand (2.0-0.005mm) Total Sand (0.05-0.002mm) Silt (0.05-0.002mm) Clay ( $<0.002$ mm)	(ft.) (percent)	5454	5455	5456	5457	5458	5459	5460		
									0.0-1.0	1.0-2.5	2.5-4.0	4.0-5.5	5.5-7.0	7.0-8.5	8.5-10.0		
AB			1-4 inches, pale brown (10YR 6/3) silt loam, brown (10YR 5/3) moist; weak, medium blocky structure, breaks to weak, fine, blocky structure; slightly hard dry, friable moist; plentiful fine roots; noncalcareous; abrupt boundary.		B <sub>2</sub>	4-10 inches, pale brown (10YR 6/3) heavy loam, brown (10YR 5/3) moist; moderate, coarse prismatic structure; breaks to moderate, coarse, medium blocky structure; hard dry, friable, moist, slightly sticky, slightly plastic wet; plentiful fine roots; noncalcareous; abrupt boundary.	BULK DENSITY (g/cm <sup>3</sup> ) (in/hr) 6 hr 24 hr	L	SICL	SICL	SICL	SIC	SICL	SICL	CL		
									0.10 0.12 22	0.06 0.08 21	0.02 0.02 24	*2/3 *	*	*	*	*	
T 2131 Bis-5455			12-30"		C <sub>Ca</sub>	10-30 inches, very pale brown (10YR 7/3) heavy loam, pale brown (10YR 6/3) moist; moderate, coarse, prismatic structure, breaks to moderate, coarse, blocky structure; hard dry, friable moist, slightly sticky, slightly plastic wet; few fine roots; strongly calcareous; abrupt boundary.	SETTLING VOLUME (ml) 1/10 bar 1/3 bar 15 bar	(percent)	39.0	35.4	38.6	46.0	41.3	41.8	36.3		
									32.1	25.5	27.0	34.8	30.4	30.5	25.0		
T 2132 Bis-5456			30-48"		C <sub>2</sub>	30-48 inches, very pale brown (10YR 7/4) light clay loam, pale brown (10YR 6/3) moist; massive structure breaks to weak, very coarse blocky structure; very hard dry, friable moist, aticky, plastic wet; strongly calcareous; gradual boundary	SOIL REACTION-PH Paste 1:5 H <sub>2</sub> O 1:2 0.01M CaCl <sub>2</sub>	7.9 7.1	8.4 7.6	9.0 8.0	8.8 8.1	8.5 7.9	8.6 7.9	8.8 7.7	7.7		
																1:2 0.01M CaCl <sub>2</sub>	
T 2133 Bis-5457			48-66"		C <sub>3</sub>	48-66 inches, pale brown (10YR 6/3) silty clay, grayish brown (10YR 5/2) moist; massive structure; very hard dry, firm moist; very sticky, plastic wet; strongly calcareous; abrupt boundary.	ORGANIC CARBON AVAILABLE PHOSPHORUS CaCO <sub>3</sub> EQUIVALENT GYPSUM REQUIREMENT SATURATION EXTRACT	(percent) (ppm) (percent) (me/100g)	-1.2	0.0	+0.4	+1.2	-0.8	+0.8	+0.9		
									SATURATION EXTRACT								
T 2134 Bis-5458			66-84"		C <sub>4</sub>	66-84 inches, pale brown (10YR 6/3) heavy silty clay loam, brown (10YR 5/3) moist; massive structure; hard dry, friable moist, aticky, plastic wet; strongly calcareous; gradual boundary.	Saturation Percentage EC <sub>e</sub> @ 25°C Ca <sup>++</sup> Mg <sup>++</sup> Na <sup>+</sup> K <sup>+</sup> CO <sub>3</sub> <sup>-</sup> HCO <sub>3</sub> <sup>-</sup> Cl <sup>-</sup> SO <sub>4</sub> <sup>-</sup> NO <sub>3</sub> <sup>-</sup> SAR Na Ca+Mg EC <sub>s</sub> @ 25°C 1:5 EXTRACT	(mmhas/cm) (me/l) (me/l) (me/l) (me/l) (me/l) (me/l) (me/l) (me/l) (me/l) (me/l) (me/l) (me/100g) (me/100g)	0.88	0.66	0.90	3.40	6.00	4.60			
									6.39	2.52	0.82	6.69	23.35	11.88			
T 2135 Bis-5459 T 2136 Bis-5460			84-102" 102-120"		C <sub>5</sub>	84-90 inches, same description as 66-84 inches. 90-120 inches, very pale brown (10YR 7/3) light clay loam, pale brown (10YR 6/3) moist; massive structure; hard dry, friable moist, sticky, slightly plastic wet; strongly calcareous.	EXCHANGEABLE SODIUM ACIDITY IN KCl exchange acidity Total Al <sup>+++</sup> NaOAc@pH 8.2 BOPON	(mmhos/cm) (me/l) (percent)	0.22	0.18	0.24	0.86	1.30	0.92	0.48		
									0.2	0.9	4.1	8.0	9.9	7.6	8.1		
						10-48-inches-lime nettings occurring in seams; medium, irregular accumulations.			17.0	15.3	20.2	26.8	23.3	23.9	17.3		

\*Denotes that no water was transmitted through soil column prior to or during the specified testing period; Fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.



Study Area: Pumpkin Creek Relief: \_\_\_\_\_ Stoniness: \_\_\_\_\_ Parent Material: \_\_\_\_\_  
Location, Sec.        Twp.        Range        Elevation: \_\_\_\_\_ Soil Series: \_\_\_\_\_  
Slope Aspect: \_\_\_\_\_ Drainage: \_\_\_\_\_ Soil Classification: \_\_\_\_\_  
Climate: \_\_\_\_\_ Vegetation: \_\_\_\_\_ Ground Water: \_\_\_\_\_  
Land Use: \_\_\_\_\_ Erosion: \_\_\_\_\_ Land Form: \_\_\_\_\_ Profile Description By: \_\_\_\_\_ Date: \_\_\_\_\_

DETERMINATION		DATA	
Laboratory Number			
Soil Number			
DEPTH			
ALUMINUM	A1		
SILVER	Ag		
ARSENIC	As		
BORON	B		
BARIUM	Ba		
BERYLLIUM	Be		
CADMIUM	Cd		
COBALT	Co		
CHROMIUM	Cr		
COPPER	Cu		
IRON	Fe		
MERCURY	Hg		
LITHIUM	Li		
MANGANESE	Mn		
MOLYBDENUM	Mo		
NICKEL	Ni		
PHOSPHOROUS	P		
LEAD	Pb		
STRONTIUM	Sr		
SELENIUM	Se		
VANADIUM	V		
ZINC	Zn		

LABORATORY DESCRIPTION		DATA	
Laboratory Number			
Soil Number			
DEPTH			
PARTICLE SIZE ANALYSIS			
Very Coarse Sand	(percent)		
Coarse Sand	(2.0-1.0 mm)		
Medium Sand	(1.0-0.5 mm)		
Fine Sand	(0.5-0.25 mm)		
Very Fine Sand	(0.25-0.10 mm)		
TOTAL SAND	(0.10-0.05 mm)		
CLAY	(2.0-0.05 mm)		
TEXTURAL CLASS (LAB)	(0.05-0.002 mm)		
BULK DENSITY	(g/cm <sup>3</sup> )		
HYDRAULIC CONDUCTIVITY	(in/hr)		
6th Hr.			
24th Hr.			
SETTLING VOLUME	(ml)		
MOISTURE RETENTION	(percent)		
1/10 bar			
1/3 bar			
15 bar			
SOIL REACTION-pH			
Paste			
1:5 H <sub>2</sub> O			
1:2 0.01 M CaCl <sub>2</sub>			
ORGANIC CARBON	(percent)		
AVAILABLE PHOSPHORUS	(ppm)		
Ca CO <sub>3</sub> EQUIVALENT	(percent)		
GYPNUM REQUIREMENT	(me/100g)		
SATURATION EXTRACT			
Saturation Percentage			
EC <sub>e</sub> @ 25 °C			
Ca++	(mmhos/cm)		
Mg++	(me/1)		
Na+	(me/1)		
K+	(me/1)		
CO <sub>3</sub> -	(me/1)		
HCO <sub>3</sub> -	(me/1)		
Cl-	(me/1)		
SO <sub>4</sub> -	(me/1)		
NO <sub>3</sub> -	(me/1)		
SAR	(me/1)		
Na	(me/100g)		
CaH <sub>2</sub>	(me/100g)		
1:5 EXTRACT			
FC <sub>e</sub> @ 25 °C	(mmhos/cm)		
CaH <sub>2</sub>	(me/1)		
EXCHANGEABLE SODIUM	(percent)		
ACIDITY			
IN KCL exchange acidity			
Total	(me/100g)		
Al+++	(me/100g)		
CATION EXCHANGE CAPACITY	(me/100g)		
NaCa+eph B.2			
BORON	(mg/l)		

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Study Area: Pumpkin Creek Relief: \_\_\_\_\_ Stoniness: \_\_\_\_\_ Parent Material: \_\_\_\_\_  
Location, Sec. \_\_\_\_\_ Twp. \_\_\_\_\_ Range \_\_\_\_\_ Elevation: \_\_\_\_\_ Soil Series: \_\_\_\_\_  
Slope Aspect: \_\_\_\_\_ Drainage: \_\_\_\_\_ Soil Classification: \_\_\_\_\_  
Vegetation: \_\_\_\_\_ Ground Water: \_\_\_\_\_  
Climate: \_\_\_\_\_ Land Use: \_\_\_\_\_ Land Form: \_\_\_\_\_ Profile Description By: \_\_\_\_\_ Date: \_\_\_\_\_

DETERMINATION		DATA	LABORATORY DESCRIPTION		DATA
Laboratory Number	6976	6977	6978	6979	6980
Stock Number	101-9	101-10	101-11	101-12	101-13
DEPTH	126, 5-134, 0 134, 0-141, 5 142, 2-154, 5 154, 5-170, 8 178, 4-204, 0 204, 0-232, 3				
ALUMINUM	A1				
SILVER	Ag				
ARSENIC	As				
BORON	B				
BARIUM	Ba				
BERYLLIUM	Be				
CADMIUM	Cd				
COBALT	Co				
CHROMIUM	Cr				
COPPER	Cu				
IRON	Fe				
MERCURY	Hg				
LITHIUM	Li				
MANGANESE	Mn				
MOLYBDENUM	Mo				
NICKEL	Ni				
PHOSPHOROUS	P				
LEAD	Pb				
STRONTIUM	Sr				
SELENIUM	Se				
VANADIUM	V				
ZINC	Zn				
PARTICLE SIZE ANALYSIS					
Very Coarse Sand					
Coarse Sand					
Medium Sand					
Fine Sand					
Very Fine Sand					
TOTAL SAND					
SILT					
CLAY					
TEXTURAL CLASS (LAB)					
BULK DENSITY					
HYDRAULIC CONDUCTIVITY					
4th Hr.					
24th Hr.					
SETTLING VOLUME					
MOISTURE RETENTION					
1/10 bar					
1/3 bar					
SOIL REACTION-pH					
Paste					
1:5 H <sub>2</sub> O					
1:2 0.01 N CaCl <sub>2</sub>					
ORGANIC CARBON					
AVAILABLE PHOSPHORUS					
Ca CO <sub>3</sub> EQUIVALENT					
CYSPUM REQUIREMENT					
SATURATION EXTRACT					
Saturation Percentage					
EC <sub>e</sub> @ 25 °C					
Ca++					
Mg++					
Na+					
K+					
CO <sub>3</sub> -					
HCO <sub>3</sub> -					
Cl-					
SO <sub>4</sub> -					
NO <sub>3</sub> -					
SAR					
Na/Ca					
1:5 EXTRACT					
PC@ 25 °C					
Ca/Mg					
EXCHANGEABLE SODIUM					
ACIDITY					
IN KCl exchange acidity					
Total					
Al+++					
CATION EXCHANGE CAPACITY					
NaOAc@pH 8.2					
BORON					

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Study Area: Pumpkin Creek Relief: \_\_\_\_\_ Stoniness: \_\_\_\_\_ Parent Material: \_\_\_\_\_  
Location, Sec. \_\_\_\_\_ Typ. \_\_\_\_\_ Range \_\_\_\_\_ Elevation: \_\_\_\_\_ Soil Series: \_\_\_\_\_  
Slope Aspect: \_\_\_\_\_ Drainage: \_\_\_\_\_ Soil Classification: \_\_\_\_\_  
Climate: \_\_\_\_\_ Ground Water: \_\_\_\_\_  
Land Use: \_\_\_\_\_ Land Form: \_\_\_\_\_ Profile Description By: \_\_\_\_\_ Date: \_\_\_\_\_

DETERMINATION		DATA		LABORATORY DESCRIPTION	
Laboratory Number				Laboratory Number	
Stack Number				Stack Number	
Depth				DEPTH	
ALUMINUM	Al			PARTICLE SIZE ANALYSIS	(Ft)
SILVER	Ag			Very Coarse Sand	(percent)
ARSENIC	As			Coarse Sand	(2.0-1.0 mm)
BORON	B			Medium Sand	(1.0-0.5 mm)
BARIUM	Ba			Fine Sand	(0.5-0.25 mm)
BERYLLIUM	Be			Very Fine Sand	(0.25-0.10 mm)
CADMIUM	Cd			TOTAL SAND	(0.10-0.05 mm)
CORAL	Co			SILT	(2.0-0.05 mm)
CHROMIUM	Cr			CLAY	(0.05-0.002 mm)
COPPER	Cu			TEXTURAL CLASS (LAB)	( 0.002 mm)
IRON	Fe			BULK DENSITY	(g/cm <sup>3</sup> )
MERCURY	Hg			HYDRAULIC CONDUCTIVITY	(in/hr)
LITHIUM	Li			6th Hr.	
MANGANESE	Mn			24th Hr.	
MOLYBDENUM	Mo			SETTLING VOLUME	(ml)
NICKEL	Ni			MOISTURE RETENTION	(percent)
PHOSPHOROUS	P			1/10 bar	
LEAD	Pb			1/3 bar	
STRONTIUM	Sr			SOIL REACTION-pH	
SELENIUM	Se			Paste	
VANADIUM	V			1:5 H <sub>2</sub> O	
ZINC	Zn			1:2 0.01 M CaCl <sub>2</sub>	
				ORGANIC CARBON	(percent)
				AVAILABLE PHOSPHORUS	(ppm)
				Ca CO <sub>3</sub> EQUIVALENT	(percent)
				GYPNUM REQUIREMENT	(me/100g)
				SATURATION EXTRACT	
				Saturation Percentage	
				EC <sub>s</sub> @ 25°C	(mmhos/cm)
				Ca <sup>++</sup>	(me/l)
				Mg <sup>++</sup>	(me/l)
				Na <sup>+</sup>	(me/l)
				K <sup>+</sup>	(me/l)
				CO <sub>3</sub> <sup>-</sup>	(me/l)
				HCO <sub>3</sub> <sup>-</sup>	(me/l)
				Cl <sup>-</sup>	(me/l)
				SO <sub>4</sub> <sup>-</sup>	(me/l)
				NO <sub>3</sub> <sup>-</sup>	(me/l)
				SAK	(me/l)
				Na	(me/100g)
				Ca+Mg	(mmhos/cm)
				1:5 EXTRACT	
				FC <sub>s</sub> @ 25°C	(me/l)
				EXCHANGEABLE SODIUM	(percent)
				ACIDITY	
				- Total	(me/100g)
				Al+++	(me/100g)
				CATION EXCHANGE CAPACITY	(me/100g)
				NaOAc@pH 8.2	(me/100g)
				BORON	(mg/l)

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.  
\*\* Routine analyses performed at the Water and Power Resources Service Laboratory, Miles City, Montana.



Study Area: Pumpkin Creek Relief: \_\_\_\_\_ Stoniness: \_\_\_\_\_ Parent Material: \_\_\_\_\_  
Location, Sec. \_\_\_\_\_ Twp. \_\_\_\_\_ Range \_\_\_\_\_ Elevation: \_\_\_\_\_ Soil Series: \_\_\_\_\_  
Slope Aspect: \_\_\_\_\_ Drainage: \_\_\_\_\_ Soil Classification: \_\_\_\_\_  
Climate: \_\_\_\_\_ Vegetation: \_\_\_\_\_ Ground Water: \_\_\_\_\_  
Land Use: \_\_\_\_\_ Erosion: \_\_\_\_\_ Land Form: \_\_\_\_\_ Profile Description By: \_\_\_\_\_ Date: \_\_\_\_\_

DETERMINATION		DATA (ppm)					LABORATORY DESCRIPTION		DATA				
Laboratory Number		10,195	10,196	10,197	10,198	10,200	Laboratory Number		10,195	10,196	10,197	10,198	10,199
Sack Number		102-1	102-2	102-3	102-4	102-6	Sack Number		102-1	102-2	102-3	102-4	102-5
Depth (Ft)		11.5-17.0	24.8-44.2	44.2-66.0	66.0-82.5	82.5-88.5	DEPTH		11.5-17.0	24.8-44.2	44.2-66.0	66.0-82.5	82.5-88.5
ALUMINUM	Al						PARTICLE SIZE ANALYSIS	(Ft)					
SILVER	Ag						Very Coarse Sand	(percent)					
ARSENIC	As						Coarse Sand	(1.0-0.5 mm)					
BORON	B	3.4	1.4	0.8	1.0	2.4	Medium Sand	(0.5-0.25 mm)					
BARIUM	Ba						Fine Sand	(0.25-0.10 mm)					
BERYLLIUM	Be						Very Fine Sand	(0.10-0.05 mm)					
CADMIUM	Cd						TOTAL SAND	(0.05-0.002 mm)					
COBALT	Co	0.08	0.20	0.08	0.10	0.16	SILT	(percent)					
CHROMIUM	Cr						CLAY	(percent)					
COPPER	Cu	1.2	13.0	3.0	3.4	13.0	TEXTURAL CLASS (LAB)						
IRON	Fe	32.8	46.0	90.0	84.0	96.0	BULK DENSITY	(g/cm <sup>3</sup> )					
MERCURY	Hg	0.050	0.260	0.189	0.234	0.523	HYDRAULIC CONDUCTIVITY	(in/hr)					
LITHIUM	Li						6th Hr.						
MANGANESE	Mn	10.2	7.8	14.4	11.6	14.0	24th Hr.						
MOLYBDENUM	Mo	<0.3	<0.3	<0.3	<0.3	<0.3	SETTLING VOLUME	(ml)					
NICKEL	Ni	0.6	6.6	2.2	3.5	7.4	MOISTURE RETENTION	(percent)					
PHOSPHORUS	P						1/10 bar						
LEAD	Pb	2.6	8.2	2.3	3.6	9.2	15 bar						
STRONTIUM	Sr						Paste						
SELENIUM	Se	0.0075	<0.003	0.012	0.012	0.072	1:2 0.01 M CaCl <sub>2</sub>						
VANADIUM	V						ORGANIC CARBON	(percent)					
ZINC	Zn	1.0	10.6	6.0	9.4	13.4	AVAILABLE PHOSPHORUS	(percent)					
							Ca CO <sub>3</sub> EQUIVALENT	(percent)					
							GYPNUM REQUIREMENT	(percent)					
							SATURATION EXTRACT	(me/100g)					
							Saturation Percentage						
							EC@ 25°C	(umhos/cm)					
							Ca++	(me/1)					
							Mg++	(me/1)					
							K+	(me/1)					
							CO <sub>3</sub> -	(me/1)					
							Cl-	(me/1)					
							SO <sub>4</sub> -	(me/1)					
							NO <sub>3</sub> -	(me/1)					
							SAR	(me/1)					
							Na	(me/100g)					
							CaH <sub>2</sub>	(me/100g)					
							1:5 EXTRACT						
							FC@ 25°C	(umhos/cm)					
							CaH <sub>2</sub>	(me/1)					
							EXCHANGEABLE SODIUM	(percent)					
							ACIDITY						
							IN KCL exchange acidity						
							- Total						
							Al+++	(me/100g)					
							CATION EXCHANGE CAPACITY	(me/100g)					
							NaOAc@pH 8.2	(me/100g)					
							BORON	(mg/l)					

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Study Area: Pumpkin Creek Relief: \_\_\_\_\_ Stoniness: \_\_\_\_\_ Parent Material: \_\_\_\_\_  
Location: Sec. \_\_\_\_\_ Twp. \_\_\_\_\_ Range \_\_\_\_\_ Elevation: \_\_\_\_\_ Soil Series: \_\_\_\_\_  
Slope Aspect: \_\_\_\_\_ Drainage: \_\_\_\_\_ Soil Classification: \_\_\_\_\_  
Climate: \_\_\_\_\_ Vegetation: \_\_\_\_\_ Ground Water: \_\_\_\_\_  
Land Use: \_\_\_\_\_ Erosion: \_\_\_\_\_ Land Form: \_\_\_\_\_ Profile Description By: \_\_\_\_\_ Date: \_\_\_\_\_

DETERMINATION		DATA		LABORATORY DESCRIPTION		DATA	
Laboratory Number	102-7			Laboratory Number		102.7	
Sack Number	140.0-154.0			Sack Number		140.0-154.0	
Depth (ft)				DEPTH	(ft)		
ALUMINUM	A1			PARTICLE SIZE ANALYSIS	(percent)		
SILVER	Ag			Very Coarse Sand	(2.0-1.0 mm)		
ARSENIC	As			Coarse Sand	(1.0-0.5 mm)		
BORON	B	0.8		Medium Sand	(0.5-0.25 mm)		
BARIUM	Ba			Fine Sand	(0.25-0.10 mm)		
BERYLLIUM	Be			Very Fine Sand	(0.10-0.05 mm)		
CADMIUM	Cd			TOTAL SAND	(2.0-0.05 mm)	1.3	
COBALT	Co			SILT	(0.05-0.002 mm)	61.7	
CHROMIUM	Cr			CLAY	(0.002 mm)	37.0	
COPPER	Cu	9.4		TEXTURAL CLASS (LAB)		SiCl	
IRON	Fe	96.0		BULK DENSITY	(g/cm <sup>3</sup> )	*1/3	
MERCURY	Hg			HYDRAULIC CONDUCTIVITY	(in/hr)	*3/5	
LITHIUM	Li			6th Hr.		154.0	
MANGANESE	Mn	0.539		24th Hr.			
MOLYBDENUM	Mo			SETTLING VOLUME	(ml)		
NICKEL	Ni			MOISTURE RETENTION	(percent)		
PHOSPHOROUS	P			1/10 bar			
LEAD	Pb	5.8		1/3 bar			
STRONTIUM	Sr			15 bar			
SELENIUM	Se	0.0043		SOIL REACTION-pH		20.2	
VANADIUM	V			Paste		9.4	
ZINC	Zn	7.2		1:5 H <sub>2</sub> O			
				1:2 0.01 N CaCl <sub>2</sub>			
				ORGANIC CARBON	(percent)		
				AVAILABLE PHOSPHORUS	(ppm)		
				Ca CO <sub>3</sub> EQUIVALENT	(percent)		
				CYPSUM REQUIREMENT	(me/100g)		
				SATURATION EXTRACT			
				Saturation Percentage			
				EC <sub>e</sub> @ 25 °C	(mmhos/cm)	61.5	
				Ca++	(me/l)	2.0	
				Mg++	(me/l)	0.88	
				Na+	(me/l)	0.72	
				K+	(me/l)	21.52	
				CO <sub>3</sub> <sup>-</sup>	(me/l)	0.22	
				HCO <sub>3</sub> <sup>-</sup>	(me/l)	0.26	
				Cl <sup>-</sup>	(me/l)	6.84	
				SO <sub>4</sub> <sup>-</sup>	(me/l)	0.69	
				NO <sub>3</sub> <sup>-</sup>	(me/l)	17.02	
				SAR	(me/l)	0.08	
				Na	(me/l)	24.0	
				Ca+Mg	(me/100g)	1.32	
				1:5 EXTRACT		0.09	
				FC <sub>s</sub> @ 25°C	(mmhos/cm)	0.45	
				Ca+Mg	(me/l)	1.21	
				EXCHANGEABLE SODIUM	(percent)	17.0	
				ACTIVITY			
				IN KCL exchange acidity			
				Total	(me/100g)		
				Al+Fe	(me/100g)		
				CATION EXCHANGE CAPACITY	(me/100g)		
				NaOAc@pH 8.2			
				BORON	(mg/l)	9.2	

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.



Study Area: Pumpkin Creek      Relief:      Stoniness:      Parent Material:      Date:       
Location, Sec.      Twp.      Range      Elevation:      Soil Series:       
Slope Aspect:      Drainage:      Soil Classification:       
Climate:      Vegetation:      Ground Water:       
Land Use:      Erosion:      Land Form:      Profile Description 8y:     

DETERMINATION		OATA (ppm)										LABORATORY DESCRIPTION		DATA			
Laboratory Number	Sack Number	103-7	103-8	103-9	103-10	103-11	103-12	103-13	103-14	103-15	103-16	103-17	103-18	103-19	103-20	103-21	103-22
Depth (ft)	86.3-94.5	94.5-115.0	115.0-131.0	131.0-145.0	145.0-159.8	159.8-191.0	191.0-204.5										
ALUMINUM	A1																
SILVER	Ag																
ARSENIC	As																
80RON	8	1.8	0.8	1.1	1.3	1.0	0.5										
BARIUM	Ba																
BERYLLIUM	Be																
CADMIUM	Cd	0.18	0.8	0.08	0.12	0.18	0.08										
COBALT	Co																
CHROMIUM	Cr																
COPPER	Cu	10.4	3.6	3.6	6.0	8.6	5.4										
IRON	Fe	94.0	80.0	120.0	142.0	124.0	80.0										
MERCURY	Hg	0.170	0.225	0.164	0.225	0.180	0.266										
LITHIUM	Li																
MANAGNESE	Mn	3.4	12.8	19.4	22.0	20.0	13.0										
MOLYBDENUM	Mo	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3										
NICKEL	Ni	5.8	2.2	2.9	3.9	4.6	1.1										
PHOSPHORUS	P																
LEAD	Pb	7.8	2.2	2.8	2.8	5.2	5.4										
STRONTIUM	Sr																
SELENIUM	Se	0.014	0.0095	0.022	0.0075	0.023	0.018										
VANADIUM	V																
ZINC	Zn	11.4	6.6	6.8	8.8	14.6	4.8										

DETERMINATION		OATA (ppm)										LABORATORY DESCRIPTION		DATA			
Laboratory Number	Sack Number	103-7	103-8	103-9	103-10	103-11	103-12	103-13	103-14	103-15	103-16	103-17	103-18	103-19	103-20	103-21	103-22
Depth (ft)	86.3-94.5	94.5-115.0	115.0-131.0	131.0-145.0	145.0-159.8	159.8-191.0	191.0-204.5										
ALUMINUM	A1																
SILVER	Ag																
ARSENIC	As																
80RON	8	1.8	0.8	1.1	1.3	1.0	0.5										
BARIUM	Ba																
BERYLLIUM	Be																
CADMIUM	Cd	0.18	0.8	0.08	0.12	0.18	0.08										
COBALT	Co																
CHROMIUM	Cr																
COPPER	Cu	10.4	3.6	3.6	6.0	8.6	5.4										
IRON	Fe	94.0	80.0	120.0	142.0	124.0	80.0										
MERCURY	Hg	0.170	0.225	0.164	0.225	0.180	0.266										
LITHIUM	Li																
MANAGNESE	Mn	3.4	12.8	19.4	22.0	20.0	13.0										
MOLYBDENUM	Mo	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3										
NICKEL	Ni	5.8	2.2	2.9	3.9	4.6	1.1										
PHOSPHORUS	P																
LEAD	Pb	7.8	2.2	2.8	2.8	5.2	5.4										
STRONTIUM	Sr																
SELENIUM	Se	0.014	0.0095	0.022	0.0075	0.023	0.018										
VANADIUM	V																
ZINC	Zn	11.4	6.6	6.8	8.8	14.6	4.8										

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

DETERMINATION		DATA (ppm)					DETERMINATION		LABORATORY DESCRIPTION					DATA				
Laboratory Number							Laboratory Number											
Sack Number							Sack Number											
Depth (Ft)							DEPTH											
		104-1	104-2	104-3	104-4	104-5	104-6			104-1	104-2	104-3	104-4	104-5	104-6			
		0-12.0	12.0-18.0	20.0-26.5	26.5-35.5	37.0-55.2	55.2-80.0			0-12.0	12.0-18.0	20.0-26.5	26.5-35.5	37.0-55.2	55.2-80.0			
ALUMINUM	Al						PARTICLE SIZE ANALYSIS											
							(percent)											
SILVER	Ag						(2.0-1.0 mm)											
ARSENIC	As						(1.0-0.5 mm)											
							(0.5-0.25 mm)											
BORON	B						(0.25-0.10 mm)											
							(0.10-0.05 mm)											
BARLIUM	Ba						(0.05-0.002 mm)											
							( 0.002 mm)											
BERYLLIUM	Be						TEXTURAL CLASS (LAB)											
							BULK DENSITY											
CADMIUM	Cd						HYDRAULIC CONDUCTIVITY											
							6th Hr.											
COBALT	Co						24th Hr.											
							SETTLING VOLUME											
CHROMIUM	Cr						MOISTURE RETENTION											
							1/10 bar											
COPPER	Cu						1/3 bar											
							15 bar											
IRON	Fe						SOIL REACTION-pH											
							Paste											
MERCURY	Hg						1:5 H <sub>2</sub> O											
							1:2 0.10 M CaCl <sub>2</sub>											
LITHIUM	Li						ORGANIC CARBON											
							AVAILABLE PHOSPHORUS											
MANGANESE	Mn						Ca CO <sub>3</sub> EQUIVALENT											
							CYSLIM REQUIREMENT											
MOLYBDENUM	Mo						SATURATION EXTRACT											
							Saturation Percentage											
NICKEL	Ni						EC@ 25°C											
							Ca++											
PHOSPHORUS	P						Mg++											
							Na+											
LEAD	Pb						K+											
							CO <sub>3</sub> -											
STRONTIUM	Sr						HCO <sub>3</sub> -											
							Cl-											
SELENIUM	Se						SO <sub>4</sub> -											
							NO <sub>3</sub> -											
VANADIUM	V						SAR											
							Na											
ZINC	Zn						Ca++											
							1:5 EXTRACT											
							EC@ 25°C											
							Ca++											
							EXCHANGEABLE SODIUM											
							ACIDITY											
							IN KCl exchange acidity											
							Total											
							Al+++											
							CATION EXCHANGE CAPACITY											
							NaOAc@pH 8.2											
							BORON											

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Study Area: Pumpkin Creek Relief: \_\_\_\_\_ Stoniness: \_\_\_\_\_ Parent Material: \_\_\_\_\_  
Location, Sec. \_\_\_\_\_ Twp. \_\_\_\_\_ Range \_\_\_\_\_ Elevation: \_\_\_\_\_ Soil Series: \_\_\_\_\_  
Slope Aspect: \_\_\_\_\_ Drainage: \_\_\_\_\_ Soil Classification: \_\_\_\_\_  
Vegetation: \_\_\_\_\_ Ground Water: \_\_\_\_\_  
Erosion: \_\_\_\_\_ Land Form: \_\_\_\_\_ Profile Description By: \_\_\_\_\_ Date: \_\_\_\_\_  
Climate: \_\_\_\_\_  
Land Use: \_\_\_\_\_

DETERMINATION		DATA (ppm)							DETERMINATION		LABORATORY DESCRIPTION						
Laboratory Number		104-7	104-8	104-9	104-10	104-11	104-12	Laboratory Number	Sack Number								
Sack Number		80.0-103.5	103.5-113.0	113.5-119.5	120.5-129.9	129.9-144.5	144.5-155.5	DEPTH	(ft)								
Depth (ft)								PARTICLE SIZE ANALYSIS	(percent)								
ALUMINUM	Al							Very Coarse Sand	(2.0-1.0 mm)								
SILVER	Ag							Coarse Sand	(1.0-0.5 mm)								
ARSENIC	As							Medium Sand	(0.5-0.25 mm)								
BORON	B	0.0	1.4	1.8	0.8	0.8	1.4	Fine Sand	(0.25-0.10 mm)								
BARIUM	Ba							Very Fine Sand	(0.10-0.05 mm)								
BERYLLIUM	Be							TOTAL SAND	(2.0-0.05 mm)								
CADMIUM	Cd	0.20	0.18	0.16	0.06	0.10	0.12	SILT	(0.05-0.002 mm)								
COBALT	Co							CLAY	(0.002 mm)								
CHROMIUM	Cr							TEXTURAL CLASS (LAB)									
COPPER	Cu	9.4	5.6	6.2	5.0	6.2	4.8	BULK DENSITY	(g/cm <sup>3</sup> )								
IRON	Fe	226.0	180.0	262.0	204.0	176.0	126.0	HYDRAULIC CONDUCTIVITY	(in/hr)								
MERCURY	Hg	0.225	0.289	0.414	0.340	0.395	0.254	6th Hr.									
LITHIUM	Li							24th Hr.									
MANGANESE	Mn	22.0	26.0	24.0	20.0	22.0	11.4	SETTLING VOLUME	(ml)								
MOLYBDENUM	Mo	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	MOISTURE RETENTION	(percent)								
NICKEL	Ni							1/10 bar									
PHOSPHORUS	P							1/3 bar									
LEAD	Pb	5.0	2.2	3.0	2.2	2.4	10.4	15 bar									
STRONTIUM	Sr							SOIL REACTION-PH									
SELENIUM	Se	0.032	0.012	0.076	0.0068	0.012	0.013	Paste									
VANADIUM	V							1:2 0.01 M CaCl <sub>2</sub>									
ZINC	Zn	11.4	7.2	11.8	4.4	5.4	15.8	ORGANIC CARBON	(percent)								
								AVAILABLE PHOSPHORUS	(ppm)								
								Ca CO <sub>3</sub> EQUIVALENT	(percent)								
								GYPSON REQUIREMENT	(me/100g)								
								SATURATION EXTRACT									
								Saturation Percentage									
								EC@ 25 C									
								Ca++	(mmhos/cm)								
								Mg++	(me/1)								
								Na+	(me/1)								
								K+	(me/1)								
								CO <sub>3</sub> -	(me/1)								
								HCO <sub>3</sub> -	(me/1)								
								Cl-	(me/1)								
								SO <sub>4</sub> -	(me/1)								
								NO <sub>3</sub> -	(me/1)								
								SAR	(me/1)								
								Na	(me/100g)								
								Ca+Mg	(mmhos/cm)								
								1:5 EXTRACT	(me/1)								
								FC@ 25°C	(percent)								
								Ca+Mg									
								EXCHANGEABLE SODIUM									
								ACIDITY									
								IN KCL exchange acidity									
								- Total									
								Al+++									
								CATION EXCHANGE CAPACITY									
								NaOAc@pH 8.2									
								BORON									

\* Denotes that no water was transmitted through soil column prior to or during the specified testin' period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Study Area: Pumpkin Creek Relief: \_\_\_\_\_ Stoniness: \_\_\_\_\_ Parent Material: \_\_\_\_\_  
Location, Sec.        Twp.        Range        Elevation: \_\_\_\_\_ Soil Series: \_\_\_\_\_  
Slope Aspect: \_\_\_\_\_ Drainage: \_\_\_\_\_ Soil Classification: \_\_\_\_\_  
Climate: \_\_\_\_\_ Vegetation: \_\_\_\_\_ Ground Water: \_\_\_\_\_  
Land Use: \_\_\_\_\_ Erosion: \_\_\_\_\_ Land Form: \_\_\_\_\_ Profile Description By: \_\_\_\_\_ Date: \_\_\_\_\_

DETERMINATION		DATA (ppm)						LABORATORY DESCRIPTION		DATA					
Laboratory Number		104-13	104-14	104-15	104-16	104-17	104-18	Laboratory Number	104-13	104-14	104-15	104-16	104-17	104-18	
Sack Number		156.7-167.0	167.5-179.5	179.5-202.7	215.5-225.0	225.0-244.0	244.0-259.5	Sack Number	156.7-167.0	167.5-179.5	179.5-202.7	215.5-225.0	225.0-244.0	244.0-259.5	
Depth (ft)								DEPTH							
ALUMINUM	Al							PARTICLE SIZE ANALYSIS							
SILVER	Ag							Very Coarse Sand							
ARSENIC	As							(2.0-1.0 mm)							
BORON	B	1.3	1.6	1.6	1.0	0.4	0.6	Coarse Sand							
BARIUM	Ba							(1.0-0.5 mm)							
BERYLLIUM	Be							Medium Sand							
CADMIUM	Cd	0.18	0.16	0.12	0.08	0.04	0.06	(0.5-0.25 mm)							
COBALT	Co							Fine Sand							
CHROMIUM	Cr							(0.25-0.10 mm)							
COPPER	Cu	9.4	6.6	7.2	4.4	2.4	6.4	Very Fine Sand							
IRON	Fe	82.0	154.0	86.0	80.0	88.0	154.0	(0.10-0.05 mm)							
MERCURY	Hg	0.392	0.327	0.392	0.440	0.119	0.388	TOTAL SAND	11.6	7.9	25.2	6.0	51.3	2.4	
LITHIUM	Li							CLAY	81.8	55.1	43.1	73.4	36.4	66.8	
MANGANESE	Mn	4.8	22.0	12.6	22.0	14.4	26.0	Si	6.6	37.0	31.7	12.3	12.3	30.8	
MOLYBDENUM	Mo	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	SiCL		SiCL	CL	SiCL	L	SiCL	
NICKEL	Ni	4.6	5.4	3.9	2.0	1.3	2.1	TEXTURAL CLASS (LAB)							
PHOSPHORUS	P							BULK DENSITY	*1/4	*1/2	*1/4	*2/3	*1/3	*1/5	
LEAD	Pb	5.2	5.2	4.6	4.2	1.8	3.2	HYDRAULIC CONDUCTIVITY	*1/3	*3/5	*1/3	*4/5	*2/5	*1/4	
STRONTIUM	Sr							6th Hr.	142.0	88.0	160.0	68.0	76.0	218.0	
SELENIUM	Se	0.012	0.18	0.035	0.029	0.014	0.018	24th Hr.							
VANADIUM	V							SETTLING VOLUME							
ZINC	Zn	12.0	10.2	7.2	5.6	4.8	7.4	MOISTURE RETENTION							
								1/10 bar	21.4	29.1	26.7	14.1	9.4	32.9	
								1/3 bar							
								15 bar							
								SOIL REACTION-pH							
								Paste	8.3	7.9	8.8	9.2	8.1	9.6	
								1:5 H <sub>2</sub> O							
								1:2 0.01 M CaCl <sub>2</sub>							
								ORGANIC CARBON							
								AVAILABLE PHOSPHORUS							
								Ca CO <sub>3</sub> EQUIVALENT							
								GYPSUM REQUIREMENT							
								SATURATION EXTRACT	+3.8	+2.8	+3.8	+2.0	+2.1	+5.1	
								Saturation Percentage	85.1	80.3	84.7	64.6	59.8	92.9	
								EC <sub>e</sub> @ 25 °C	4.7	6.7	3.2	3.8	2.2	1.3	
								Ca++	4.39	11.14	1.10	2.09	0.49	0.16	
								Mg++	3.53	8.05	0.63	1.63	0.27	0.09	
								Na+	37.97	55.96	29.37	32.28	20.18	13.39	
								K+	0.25	0.34	0.17	0.23	0.18	0.10	
								CO <sub>3</sub> -	0.14	0.81	0.28	0.00	0.23	0.57	
								HCO <sub>3</sub> -	4.69	9.86	6.39	6.96	4.91	6.00	
								Cl-	0.72	1.62	0.93	0.86	0.85	0.74	
								SO <sub>4</sub> -	40.56	62.12	23.47	28.71	14.70	5.26	
								NO <sub>3</sub> -	2.23	3.18	1.62	3.74	0.82	0.74	
								Na	19.0	18.0	32.0	25.0	38.0	36.0	
								Ca+Mg	3.23	4.49	2.49	2.09	1.21	1.24	
								1:5 EXTRACT	0.67	1.54	0.14	0.23	0.05	0.02	
								FC <sub>53</sub> @ 25°C	0.96	1.5	0.79	0.66	0.50	0.56	
								Ca+Mg	0.67	1.54	1.62	1.04	1.10	2.38	
								EXCHANGEABLE SODIUM	17.0	13.0	26.0	11.0	28.0	29.0	
								ACIDITY							
								IN KCL exchange acidity							
								- Total							
								Al+++							
								CATION EXCHANGE CAPACITY	19.0	24.0	18.0	18.0	8.2	17.0	
								NaOAc@pH 8.2							
								BORON							

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Study Area: Pumpkin Creek      Relief:      Stoniness:      Parent Material:      Date:      5'

Location, Sec.      Top.      Range      Elevation:      Soil Series:      Soil Classification:

Slope Aspect:      Drainage:      Ground Water:      Profile Description 8y:      Land Use:      Erosion:      Vegetation:      Climate:      Land Form:

DETERMINATION		DATA (ppm)	LABORATORY DESCRIPTION	
Laboratory Number			Laboratory Number	OATA
Sack Number	104-19		Sack Number	272.0-289.5
Depth (ft)	272.0-289.5		DEPTH	
ALUMINUM	Al		PARTICLE SIZE ANALYSIS	(Ft)
SILVER	Ag		Very Coarse Sand	(percent)
ARSENIC	As		Coarse Sand	(2.0-1.0 mm)
BORON	B	0.6	Medium Sand	(1.0-0.5 mm)
BARIUM	Ba		Fine Sand	(0.5-0.25 mm)
BERYLLIUM	Be		Very Fine Sand	(0.25-0.10 mm)
CADMIUM	Cd	0.06	TOTAL SAND	(2.0-0.05 mm)
COBALT	Co		SILT	(0.05-0.002 mm)
CHROMIUM	Cr		CLAY	( 0.002 mm)
COPPER	Cu	6.2	TEXTURAL CLASS (LAB)	
IRON	Fe	98.0	BULK DENSITY	(g/cm <sup>3</sup> )
MERCURY	Hg	0.498	HYDRAULIC CONDUCTIVITY	(in/hr)
LITHIUM	Li		6th Hr.	*1/4
MANGANESE	Mn	19.8	24th Hr.	*2/5
MOLYBDENUM	Mo	<0.3	SETTLING VOLUME	(ml)
NICKEL	Ni	1.9	MOISTURE RETENTION	(percent)
PHOSPHORUS	P		1/10 bar	114.0
LEAD	Pb	4.6	1/3 bar	
STRONTIUM	Sr		15 bar	14.6
SELENIUM	Se	0.019	SOIL REACTION-pH	
VANADIUM	V		Paste	9.5
ZINC	Zn	5.2	1:5 H <sub>2</sub> O	
			1:2 0.01 M CaCl <sub>2</sub>	
			ORGANIC CARBON	(percent)
			AVAILABLE PHOSPHORUS	(ppm)
			Ca CO <sub>3</sub> EQUIVALENT	(percent)
			GYPSUM REQUIREMENT	(me/100g)
			SATURATION EXTRACT	
			Saturation Percentage	(mmhos/cm)
			EC@ 25 °C	48.6
			Ca++	2.7
			Mg++	0.99
			Na+	0.72
			K+	24.49
			CO <sub>3</sub> -	0.19
			Cl-	0.36
			SO <sub>4</sub> -	6.29
			NO <sub>3</sub> -	0.99
			SAR	18.83
			Na	2.10
			Ca/Hg	26.0
			1:5 EXTRACT	1.19
			FC@ 25°C	0.08
			Ca/Hg	0.46
			EXCHANGEABLE SODIUM	1.13
			ACIDITY	21.0
			IN KCL exchange acidity	
			Total	(me/100g)
			Al+++	(me/100g)
			CATION EXCHANGE CAPACITY	(me/100g)
			NaOAc@pH 8.2	9.0
			BORON	(mg/l)

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Study Area: Pumpkin Creek Relief:                      Stoniness:                      Parent Material:                     

Location, Sec.                      Twp.                      Range                      Elevation:                      Soil Series:                     

Slope Aspect:                      Drainage:                      Soil Classification:                     

Climate:                      Vegetation:                      Ground Water:                     

Land Use:                      Erosion:                      Land Form:                      Profile Description By:                      Date:                     

DETERMINATION		DATA (ppm)						DETERMINATION		LABORATORY DESCRIPTION						DATA											
Laboratory Number								Laboratory Number																			
Sack Number								Sack Number																			
Depth (Ft)								Depth (Ft)																			
ALUMINUM	Al	105-1	105-2	105-3	105-4	105-5	105-6	PARTICLE SIZE ANALYSIS (percent) (2.0-1.0 mm) (1.0-0.5 mm) (0.5-0.25 mm) (0.25-0.10 mm) (0.10-0.05 mm) (2.0-0.05 mm) (0.05-0.002 mm) ( 0.002 mm)	105-1	105-2	105-3	105-4	105-5	105-6	0-15.8	15.8-26.8	26.8-40.0	40.0-50.5	50.5-62.0	62.0-77.0							
	SILVER	Ag																									
	ARSENIC	As																									
	BORON	B	0.4	0.8	0.5	0.5	1.0														0.5						
BARIUM	Ba							TEXTURAL CLASS (LAB) BULK DENSITY (g/cm <sup>3</sup> ) (in/hr) 6th Hr. 24th Hr. SETTLING VOLUME (ml) MOISTURE RETENTION (percent) 1/10 bar 1/3 bar 15 bar SOIL REACTION-pH Paste 1:5 H <sub>2</sub> O 1:2 0.01 M CaCl <sub>2</sub> ORGANIC CARBON (percent) Ca CO <sub>3</sub> EQUIVALENT (ppm) GYPSUM REQUIREMENT (me/100g) SATURATION EXTRACT Saturation Percentage EC <sub>e</sub> @ 25°C Ca++ Mg++ Na+ K+ CO <sub>3</sub> - HCO <sub>3</sub> - Cl- SO <sub>4</sub> - NO <sub>3</sub> - SAR Na Ca+Mg 1:5 EXTRACT FC <sub>s</sub> @ 25°C Ca+Mg EXCHANGEABLE SODIUM (me/100g) ACIDITY IN KCL exchange acidity — Total Al+++ NaOAc@pH 8.2 BORON	105-1	105-2	105-3	105-4	105-5	105-6	0-15.8	15.8-26.8	26.8-40.0	40.0-50.5	50.5-62.0	62.0-77.0							
BERYLLIUM	Be																										
CADMIUM	Cd	0.16	0.12	0.06	0.08	0.14	0.04																				
COBALT	Co																										
CHROMIUM	Cr							105-1	105-2	105-3	105-4	105-5	105-6	0-15.8	15.8-26.8	26.8-40.0	40.0-50.5	50.5-62.0	62.0-77.0								
COPPER	Cu	5.6	4.0	2.0	4.8	3.4	7.0																				
IRON	Fe	132.0	110.0	36.0	94.0	154.0	268.0																				
MERCURY	Hg	0.128	0.144	0.061	0.308	0.225	0.318																				
LITHIUM	Li							105-1	105-2	105-3	105-4	105-5	105-6	0-15.8	15.8-26.8	26.8-40.0	40.0-50.5	50.5-62.0	62.0-77.0								
MANGANESE	Mn	8.8	10.2	4.8	15.0	16.8	20.0																				
MOLYBDENUM	Mo	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3																				
NICKEL	Ni	0.8	2.7	0.7	2.4	2.4	1.8																				
PHOSPHORUS	P							105-1	105-2	105-3	105-4	105-5	105-6	0-15.8	15.8-26.8	26.8-40.0	40.0-50.5	50.5-62.0	62.0-77.0								
LEAD	Pb	4.8	1.6	1.2	3.0	1.6	4.0																				
STRONTIUM	Sr																										
SELENIUM	Se	0.015	<0.003	<0.003	0.0057	0.012	0.015																				
VANADIUM	V							105-1	105-2	105-3	105-4	105-5	105-6	0-15.8	15.8-26.8	26.8-40.0	40.0-50.5	50.5-62.0	62.0-77.0								
ZINC	Zn	9.4	4.0	1.2	4.1	4.3	5.2																				

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Study Area: Pumpkin Creek Relief:                      Stoniness:                      Parent Material:                       
Location, Sec.                      Twp.                      Range                      Elevation:                      ft. Soil Series:                       
Slope Aspect:                      Drainage:                      Soil Classification:                       
Climate:                      Vegetation:                      Ground Water:                       
Land Use:                      Erosion:                      Land Form:                      Profile Description By:                      Date:                     

DETERMINATION		DATA (ppm)						LABORATORY DESCRIPTION		DATA					
Laboratory Number		105-7	105-8	105-9	105-10	105-11	105-12	Laboratory Number		105-7	105-8	105-9	105-10	105-11	105-12
Sack Number		77.0-94.5	94.5-108.5	109.0-130.0	130.0-142.0	142.0-161.2	161.2-174.0	Sack Number		77.0-94.5	94.5-108.5	109.0-130.0	130.0-142.0	142.0-161.2	161.2-174.0
Depth (ft)								DEPTH							
ALUMINUM	Al							PARTICLE SIZE ANALYSIS							
SILVER	Ag							(percent)							
ARSENIC	As							(2.0-1.0 mm)							
BORON	B	0.5	0.9	0.7	1.4	1.0	0.8	(1.0-0.5 mm)							
BARIUM	Ba							(0.5-0.25 mm)							
BERYLLIUM	Be							(0.25-0.10 mm)							
CADMIUM	Cd	0.08	0.18	0.06	0.08	0.10	0.08	(0.10-0.05 mm)							
COBALT	Co							(0.05-0.002 mm)							
CHROMIUM	Cr							(0.002 mm)							
COPPER	Cu	6.8	13.8	6.0	3.4	2.6	2.4	(g/cm <sup>3</sup> )							
IRON	Fe	106.0	176.0	110.0	104.0	104.0	106.0	(lb/hr)							
MERCURY	Hg	0.347	0.395	0.347	0.273	0.295	0.189	6th Hr.							
LITHIUM	Li							24th Hr.							
MANGANESE	Mn	10.4	14.2	7.0	6.6	9.4	12.0	SETTLING VOLUME							
MOLYBDENUM	Mo	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	MOISTURE RETENTION							
NICKEL	Ni	2.2	5.6	2.3	1.9	3.0	2.9	1/10 bar							
PHOSPHOROUS	P							1/3 bar							
LEAD	Pb	4.6	6.8	4.6	2.6	3.6	2.4	1/5 bar							
STRONTIUM	Sr							SOIL REACTION-PH							
SELENIUM	Se	0.016	0.030	0.023	0.030	0.31	0.025	Paste							
VANADIUM	V							1:5 H <sub>2</sub> O							
ZINC	Zn	7.7	12.6	7.4	7.4	7.2	6.2	1:2 0.01 M CaCl <sub>2</sub>							
								ORGANIC CARBON							
								AVAILABLE PHOSPHORUS							
								Ca CO <sub>3</sub> EQUIVALENT							
								CYSPUM REQUIREMENT							
								SATURATION EXTRACT							
								Saturation Percentage							
								EC@ 25 C							
								Ca++							
								Mg++							
								Na+							
								K+							
								CO <sub>3</sub> -							
								HCO <sub>3</sub> -							
								Cl-							
								SO <sub>4</sub> -							
								NO <sub>3</sub> -							
								SAR							
								Na							
								Ca+Mg							
								1:5 EXTRACT							
								EC@ 25 C							
								Ca+Mg							
								EXCHANGEABLE SODIUM							
								ACIDITY							
								IN KCL exchange acidity							
								Total							
								Al+++							
								CATION EXCHANGE CAPACITY							
								NaOAc@pH 8.2							
								BORON							

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Study Area: Pumpkin Creek Relief: \_\_\_\_\_ Stoniness: \_\_\_\_\_ Parent Material: \_\_\_\_\_  
Location, Sec. 174.0-189.5 Range 105-16 Twp. 236.3-251.5 Elevation: \_\_\_\_\_ Soil Series: \_\_\_\_\_  
Slope Aspect: \_\_\_\_\_ Drainage: \_\_\_\_\_ Soil Classification: \_\_\_\_\_  
Climate: \_\_\_\_\_ Vegetation: \_\_\_\_\_ Ground Water: \_\_\_\_\_  
Land Use: \_\_\_\_\_ Erosion: \_\_\_\_\_ Land Form: \_\_\_\_\_ Profile Description By: \_\_\_\_\_ Date: \_\_\_\_\_

DETERMINATION		DATA (ppm)				LABORATORY DESCRIPTION		DATA			
Laboratory Number		105-13	105-14	105-15	105-16	Laboratory Number		105-13	105-14	105-14	105-16
Sack Number		174.0-189.5	190.0-198.0	198.0-222.5	236.3-251.5	Sack Number		174.0-189.5	190.0-198.0	198.0-222.5	236.3-251.5
Depth (ft)						DEPTH					
ALUMINUM	Al					PARTICLE SIZE ANALYSIS	(percent)				
SILVER	Ag					Very Coarse Sand	(2.0-1.0 mm)				
ARSENIC	As					Coarse Sand	(1.0-0.5 mm)				
BORON	B	1.2	0.8	1.0	2.1	Medium Sand	(0.5-0.25 mm)				
BARIUM	Ba					Fine Sand	(0.25-0.10 mm)				
BERYLLIUM	Be					Very Fine Sand	(0.10-0.05 mm)	6.1	22.3	6.7	7.3
CADMIUM	Cd					TOTAL SAND	(2.0-0.05 mm)	68.8	56.3	57.5	71.7
COBALT	Co					CLAY	(0.05-0.002 mm)	25.1	21.4	35.8	21.6
CHROMIUM	Cr	0.16	0.10	0.12	0.12	TEXTURAL CLASS (LAB)		51L	51L	51L	51L
COPPER	Cu	4.4	4.2	11.0	6.0	BULK DENSITY	(g/cm <sup>3</sup> )	*1/5	*1/4	*1/3	*1/3
IRON	Fe	156.0	104.0	126.0	122.0	HYDRAULIC CONDUCTIVITY	(in/hr)	*1/4	*1/3	*1/5	*1/2
MERCURY	Hg	0.292	0.305	0.485	0.401	6th Hr.		190.0	152.0	316.0	104.0
LITHIUM	Li					24th Hr.					
MANGANESE	Mn	18.8	14.8	17.6	9.6	SETTLING VOLUME	(ml)	23.8	25.4	22.4	14.5
MOLYBDENUM	Mo	<0.3	<0.3	<0.3	<0.3	MOISTURE RETENTION	(percent)	9.1	9.1	9.1	8.1
NICKEL	Ni	0.5	3.7	4.3	4.0	1/3 bar					
PHOSPHORUS	P					15 bar					
LEAD	Pb	4.2	3.8	9.0	8.2	SOIL REACTION-PH					
STRONTIUM	Sr					Faste					
SELENIUM	Se	0.010	0.052	0.060	0.024	1:5 H <sub>2</sub> O					
VANADIUM	V	10.8	9.4	11.6	7.0	1:2 0.01 M CaCl <sub>2</sub>					
ZINC	Zn					ORGANIC CARBON	(percent)				
						AVAILABLE PHOSPHORUS	(ppm)				
						Ca CO <sub>3</sub> EQUIVALENT	(percent)				
						GYPNUM REQUIREMENT	(me/100g)				
						SATURATION EXTRACT					
						Saturation Percentage					
						EC <sub>e</sub> @ 25 °C	(umhos/cm)	+7.1	+5.2	+5.8	+1.3
						Ca++	(me/1)	86.9	64.9	42.4	56.3
						Mg++	(me/1)	1.9	2.8	3.1	2.4
						K+	(me/1)	0.77	1.76	4.12	0.71
						CO <sub>3</sub> -	(me/1)	0.36	1.36	3.35	0.45
						Cl-	(me/1)	22.33	31.09	29.13	20.61
						SO <sub>4</sub> -	(me/1)	0.15	0.18	0.30	0.15
						NO <sub>3</sub> -	(me/1)	0.32	0.00	0.00	0.44
						SAR	(me/1)	5.64	5.12	5.08	7.28
						Na	(me/1)	0.10	0.16	0.32	1.20
						Ca+Mg	(me/1)	21.67	31.88	33.68	15.24
						1:5 EXTRACT	(me/100g)	30.0	25.0	15.0	0.42
						Ca+Mg	(me/100g)	1.94	2.02	1.24	1.16
						EC <sub>e</sub> @ 25 °C	(umhos/cm)	0.10	0.20	0.31	0.35
						EXCHANGEABLE SODIUM	(me/100g)	0.6	0.6	0.6	0.5
						ACIDITY	(percent)	1.88	1.68	1.90	0.93
						IN KCl exchange acidity		25.0	24.0	22.0	13.0
						Total	(me/100g)				
						Al+++	(me/100g)				
						CATION EXCHANGE CAPACITY	(me/100g)				
						NaOAc@pH 8.2	(mg/l)				
						BORON					
								21.0	17.0	22.0	13.0

\* Denotes that no water was transmitted thru gh soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.



Study Area: Pumpkin Creek Relief: \_\_\_\_\_ Stoniness: \_\_\_\_\_ Parent Material: \_\_\_\_\_  
Location, Sec. \_\_\_\_\_ Twp. \_\_\_\_\_ Range \_\_\_\_\_ Elevation: \_\_\_\_\_ Soil Series: \_\_\_\_\_  
Slope Aspect: \_\_\_\_\_ Drainage: \_\_\_\_\_ Soil Classification: \_\_\_\_\_  
Climate: \_\_\_\_\_ Vegetation: \_\_\_\_\_ Ground Water: \_\_\_\_\_  
Land Use: \_\_\_\_\_ Land Form: \_\_\_\_\_ Profile Description 8y: \_\_\_\_\_ Date: \_\_\_\_\_

DETERMINATION		DATA	LABORATORY DESCRIPTION		DATA
Laboratory Number			Laboratory Number		
Soil Number			Soil Number		
Depth			Depth		
ALUMINUM	Al		DEPTH	(ft)	
SILVER	Ag		PARTICLE SIZE ANALYSIS	(percent)	
ARSENIC	As		Very Coarse Sand	(2.0-1.0 mm)	
BORON	B		Coarse Sand	(1.0-0.5 mm)	
BARIUM	Ba		Medium Sand	(0.5-0.25 mm)	
BERYLLIUM	Be		Fine Sand	(0.25-0.10 mm)	
CADMIUM	Cd		Very Fine Sand	(0.10-0.05 mm)	
CORAL	Co		CLAY	(0.05-0.002 mm)	
CHROMIUM	Cr		TEXTURAL CLASS (LAB)	(g/cm <sup>3</sup> )	
COPPER	Cu		BULK DENSITY	(in/hr)	
IRON	Fe		HYDRAULIC CONDUCTIVITY		
MERCURY	Hg		6th Hr.		
LITHIUM	Li		24th Hr.		
MANGANESE	Mn		SETTLING VOLUME	(ml)	
MOLYBDENUM	Mo		MOISTURE RETENTION	(percent)	
NICKEL	Ni		1/10 bar		
PHOSPHOROUS	P		1/3 bar		
LEAD	Pb		15 bar		
STRONTIUM	Sr		SOIL REACTION-pH		
SELENIUM	Se		Paste		
VANADIUM	V		1:5 H <sub>2</sub> O		
ZINC	Zn		1:2 0.01 M CaCl <sub>2</sub>		
			ORGANIC CARBON		
			AVAILABLE PHOSPHORUS		
			Ca CO <sub>3</sub> EQUIVALENT		
			GYPSED REQUIREMENT		
			SATURATION EXTRACT		
			Saturation Percentage		
			EC <sub>e</sub> @ 25 °C		
			Ca++	(me/l)	
			Mg++	(me/l)	
			Na+	(me/l)	
			K+	(me/l)	
			CO <sub>3</sub> -	(me/l)	
			HCO <sub>3</sub> -	(me/l)	
			Cl-	(me/l)	
			SO <sub>4</sub> -	(me/l)	
			NO <sub>3</sub> -	(me/l)	
			SAR	(me/l)	
			Na	(me/100g)	
			Ca+Mg	(me/100g)	
			1:5 EXTRACT		
			FC <sub>5.3</sub> 25°C	(mmhos/cm)	
			Ca+Mg	(me/l)	
			EXCHANGEABLE SODIUM	(percent)	
			ACIDITY		
			IN KCL exchange acidity		
			- Total	(me/100g)	
			Al+++	(me/100g)	
			CATION EXCHANGE CAPACITY	(me/100g)	
			NaOAc@pH 8.2	(me/100g)	
			BORON	(mg/l)	

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Study Area: Pumpkin Creek Relief: \_\_\_\_\_ Stoniness: \_\_\_\_\_ Parent Material: \_\_\_\_\_  
Location, Sec. \_\_\_\_\_ Twp. \_\_\_\_\_ Range \_\_\_\_\_ Elevation: \_\_\_\_\_ Soil Series: \_\_\_\_\_  
Slope Aspect: \_\_\_\_\_ Drainage: \_\_\_\_\_ Soil Classification: \_\_\_\_\_  
Climate: \_\_\_\_\_ Ground Water: \_\_\_\_\_  
Land Use: \_\_\_\_\_ Land Form: \_\_\_\_\_ Profile Description By: \_\_\_\_\_ Date: \_\_\_\_\_

DETERMINATION		DATA	LABORATORY DESCRIPTION		DATA
Laboratory Number	10,255		Laboratory Number	10,255	10,257
Soil Number	106-7		Soil Number	106-8	106-9
DEPTH	95.0-104.5		DEPTH	104.5-116.3	116.3-123.5
ALUMINUM			Very Coarse Sand		
SILVER			Coarse Sand		
ARSENIC			Medium Sand		
BORON			Fine Sand		
BARIUM			Very Fine Sand		
BERYLLIUM			TOTAL SAND		
CADMIUM			SILT		
COBALT			CLAY		
CHROMIUM			TEXTURAL CLASS (LAB)		
COPPER			AIR DENSITY		
IRON			HYDRAULIC CONDUCTIVITY		
MERCURY			6th Hr.		
LITHIUM			24th Hr.		
MANGANESE			SETTLING VOLUME		
MOLYBDENUM			MOISTURE RETENTION		
NICKEL			1/10 bar		
PHOSPHOROUS			1/3 bar		
LEAD			15 bar		
STRONTIUM			SOIL REACTION-pH		
SELENIUM			Paste		
VANADIUM			1:5 H <sub>2</sub> O		
ZINC			1:2 0.01 M CaCl <sub>2</sub>		
			ORGANIC CARBON		
			AVAILABLE PHOSPHORUS		
			Ca CO <sub>3</sub> EQUIVALENT		
			GYPHONIUM REQUIREMENT		
			SATURATION EXTRACT		
			Saturation Percentage		
			EC @ 25°C		
			Ca++		
			Mg++		
			Na+		
			K+		
			CO <sub>3</sub>		
			HCO <sub>3</sub>		
			Cl-		
			SO <sub>4</sub>		
			NO <sub>3</sub>		
			SAR		
			Na		
			CaHlg		
			1:5 EXTRACT		
			FG 3 25°C		
			CaHlg		
			EXCHANGEABLE SODIUM		
			ACIDITY		
			IN KCl exchange acidity		
			- Total		
			Al+++		
			CATION EXCHANGE CAPACITY		
			NaOAc@pH 8.2		
			BORON		

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Study Area: Pumpkin Creek Relief: \_\_\_\_\_ Stoniness: \_\_\_\_\_ Parent Material: \_\_\_\_\_  
Location, Sec.        Twp.        Range        Elevation: \_\_\_\_\_ Soil Series: \_\_\_\_\_  
Slope Aspect: \_\_\_\_\_ Drainage: \_\_\_\_\_ Soil Classification: \_\_\_\_\_  
Climate: \_\_\_\_\_ Vegetation: \_\_\_\_\_ Ground Water: \_\_\_\_\_  
Land Use: \_\_\_\_\_ Erosion: \_\_\_\_\_ Land Form: \_\_\_\_\_ Profile Description By: \_\_\_\_\_ Date: \_\_\_\_\_

DETERMINATION		DATA	
Laboratory Number			
Soil Number			
DEPTH			
PARTICLE SIZE ANALYSIS			
	(Ft)		
	(percent)		
	(2.0-1.0 mm)		
	(1.0-0.5 mm)		
	(0.5-0.25 mm)		
	(0.25-0.10 mm)		
	(0.10-0.05 mm)		
	(2.0-0.05 mm)		
	(0.05-0.002 mm)		
	( 0.002 mm)		
TOTAL SAND			
CLAY			
TEXTURAL CLASS (LAB)			
BULK DENSITY	(g/cm <sup>3</sup> )		
HYDRAULIC CONDUCTIVITY	(in/hr)		
6th Hr.			
24th Hr.			
SETTLING VOLUME	(ml)		
MOISTURE RETENTION	(percent)		
1/10 bar			
1/3 bar			
15 bar			
SOIL REACTION-pH			
Paste			
1:5 H <sub>2</sub> O			
1:2 0.01 M CaCl <sub>2</sub>			
ORGANIC CARBON	(percent)		
AVAILABLE PHOSPHORUS	(ppm)		
Ca CO <sub>3</sub> EQUIVALENT	(percent)		
CYSLIM REQUIREMENT	(me/100g)		
SATURATION EXTRACT			
Saturation Percentage			
EC @ 25 °C	(mmhos/cm)		
Ca++	(me/l)		
Mg++	(me/l)		
Na+	(me/l)		
K+	(me/l)		
CO <sub>3</sub> -	(me/l)		
HCO <sub>3</sub> -	(me/l)		
Cl-	(me/l)		
SO <sub>4</sub> -	(me/l)		
NO <sub>3</sub> -	(me/l)		
SAR	(me/l)		
Na	(me/100g)		
CaH <sub>2</sub>	(me/100g)		
1:5 EXTRACT			
FC @ 25 °C	(mmhos/cm)		
CaH <sub>2</sub>	(me/l)		
EXCHANGEABLE SODIUM			
ACIDITY	(percent)		
IN KCL exchange acidity			
Total	(me/100g)		
Al+++	(me/100g)		
CATION EXCHANGE CAPACITY	(me/100g)		
NaOH-c@pH 8.2			
BORON	(mg/l)		

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Study Area: Pumpkin Creek Relief: \_\_\_\_\_ Stoniness: \_\_\_\_\_ Parent Material: \_\_\_\_\_  
Location. Sec.        Twp.        Range        Elevation: \_\_\_\_\_ Soil Series: \_\_\_\_\_  
Slope Aspect: \_\_\_\_\_ Drainage: \_\_\_\_\_ Soil Classification: \_\_\_\_\_  
Climate: \_\_\_\_\_ Ground Water: \_\_\_\_\_  
Land Use: \_\_\_\_\_ Land Form: \_\_\_\_\_ Profile Description By: \_\_\_\_\_ Date: \_\_\_\_\_

DETERMINATION		DATA	
Laboratory Number			
Stock Number		10,265	10,266
DEPTH		107-7	107-8
PARTICLE SIZE ANALYSIS		88.0-0-117.8	151.8-164.5
Very Coarse Sand	(percent)		
(2.0-1.0 mm)			
Coarse Sand	(percent)		
(1.0-0.5 mm)			
Medium Sand	(percent)		
(0.5-0.25 mm)			
Fine Sand	(percent)		
(0.25-0.10 mm)			
Very Fine Sand	(percent)		
(0.10-0.05 mm)			
TOTAL SAND	(percent)		34.0
SILT	(percent)		47.6
CLAY	(percent)		18.4
TEXTURAL CLASS (LAB)			L
BULK DENSITY	(g/cm <sup>3</sup> )		
HYDRAULIC CONDUCTIVITY	(in/hr)		
6th Hr.		*1/4	*1/3
24th Hr.		*1/4	*1/2
SETTLING VOLUME	(ml)		
MOISTURE RETENTION	(percent)		
1/10 bar		29.9	8.1
15 bar			
SOIL REACTION-pH		9.2	9.4
Paste			
1:5 H <sub>2</sub> O			
1:2 0.01 M CaCl <sub>2</sub>			
ORGANIC CARBON	(percent)		
AVAILABLE PHOSPHORUS	(ppm)		
Ca CO <sub>3</sub> EQUIVALENT	(percent)		
GYPNUM REQUIREMENT	(me/100g)	+5.0	+1.3
SATURATION EXTRACT			
Saturation Percentage			
EC <sub>e</sub> @ 25 °C	(mmhos/cm)	1.9	1.7
Ca++	(me/l)		
Mg++	(me/l)		
Na+	(me/l)		
K+	(me/l)		
CO <sub>3</sub> -	(me/l)		
HCO <sub>3</sub> -	(me/l)		
Cl-	(me/l)		
SO <sub>4</sub> -	(me/l)		
NO <sub>3</sub> -	(me/l)		
SAR	(me/l)		
Na	(me/100g)	23.0	28.0
Ca+Mg	(me/100g)		
1:5 EXTRACT			
EC <sub>e</sub> @ 25 °C	(mmhos/cm)	0.63	0.22
Ca+Mg	(me/l)	2.24	0.99
EXCHANGEABLE SODIUM	(percent)		
ACIDITY			
IN KCL exchange acidity			
Total	(me/100g)		
Al+++	(me/100g)		
CATION EXCHANGE CAPACITY	(me/100g)		
NaOAc@pH 8.2	(mg/l)		
BORON			

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Study Area: Pumpkin Creek Relief: \_\_\_\_\_ Stoniness: \_\_\_\_\_ Parent Material: \_\_\_\_\_  
Location, Sec. \_\_\_\_\_ Twp. \_\_\_\_\_ Range \_\_\_\_\_ Elevation: \_\_\_\_\_ Soil Series: \_\_\_\_\_  
Slope Aspect: \_\_\_\_\_ Drainage: \_\_\_\_\_ Soil Classification: \_\_\_\_\_  
Climate: \_\_\_\_\_ Vegetation: \_\_\_\_\_ Ground Water: \_\_\_\_\_  
Land Use: \_\_\_\_\_ Erosion: \_\_\_\_\_ Land Form: \_\_\_\_\_ Profile Description 8y: \_\_\_\_\_ Date: \_\_\_\_\_

DETERMINATION		DATA	LABORATORY DESCRIPTION		DATA
Laboratory Number			Laboratory Number		
Stock Number			Stock Number		
Depth			Depth		
ALUMINUM	Al		Very Coarse Sand	(ft)	10,267 10,268 10,270 10,271
SILVER	Ag		(1.0-0.5 mm)	(percent)	108-1 108-2 108-3 108-4 108-5
ARSENIC	As		Coarse Sand	(0.5-0.25 mm)	0.0-20.0 20.0-40.0 40.0-65.0 65.0-87.8 118.7-134.0
BORON	B		Medium Sand	(0.25-0.10 mm)	
BARIUM	Ba		Fine Sand	(0.10-0.05 mm)	
BERYLLIUM	Be		Very Fine Sand	(0.05-0.02 mm)	
CADMIUM	Cd		(0.02-0.01 mm)	(percent)	
COBALT	Co		(0.01-0.005 mm)	(0.05-0.002 mm)	
CHROMIUM	Cr		CLAY	(0.002 mm)	
COPPER	Cu		TEXTURAL CLASS (LAS)	(g/cm <sup>3</sup> )	
IRON	Fe		BULK DENSITY	(in/hr)	
MERCURY	Hg		HYDRAULIC CONDUCTIVITY		
LITHIUM	Li		6th Hr.		
MANGANESE	Mn		24th Hr.		
MOYBDENUM	Mo		SETTLING VOLUME	(ml)	
NICKEL	Ni		MOISTURE RETENTION	(percent)	
PHOSPHORUS	P		1/10 bar		
LEAD	Pb		1/3 bar		
STRONTIUM	Sr		15 bar		
SELENIUM	Se		SOIL REACTION-PH		
VANADIUM	V		Paste		
ZINC	Zn		1:5 H <sub>2</sub> O		
			1:2 0.01 M CaCl <sub>2</sub>		
			ORGANIC CARBON		
			AVAILABLE PHOSPHORUS	(percent)	
			Ca CO <sub>3</sub> EQUIVALENT	(ppm)	
			GYPSON REQUIREMENT	(percent)	
			SATURATION EXTRACT	(me/100g)	
			Saturation Percentage		
			ECe@ 25 C	(mmhos/cm)	
			Ca++	(me/l)	
			Mg++	(me/l)	
			Na+	(me/l)	
			K+	(me/l)	
			CO <sub>3</sub> -	(me/l)	
			HCO <sub>3</sub> -	(me/l)	
			Cl-	(me/l)	
			SO <sub>4</sub> -	(me/l)	
			NO <sub>3</sub> -	(me/l)	
			SAR	(me/l)	
			Na	(me/100g)	
			Ca+Mg	(me/100g)	
			1:5 EXTRACT		
			FC@ 25°C	(mmhos/cm)	
			Ca+Mg	(me/l)	
			EXCHANGEABLE SODIUM	(percent)	
			ACIDITY		
			IN KCL exchange acidity		
			Total	(me/100g)	
			Al+++	(me/100g)	
			CATION EXCHANGE CAPACITY	(me/100g)	
			NaOAc@pH 8.2		
			BORON	(mg/l)	

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.



Study Area: Pumpkin Creek      Relief:      Stoniness:      Parent Material:      Date:        
Location, Sec.      Twp.      Range      Elevation:      Soil Series:        
Slope Aspect:      Drainage:      Soil Classification:        
Climate:      Vegetation:      Ground Water:      Profile Description By:        
Land Use:      Erosion:      Land Form:     

DETERMINATION		DATA		LABORATORY DESCRIPTION		DATA	
Laboratory Number		Laboratory Number		Laboratory Number		Laboratory Number	
Stock Number		Stock Number		Stock Number		Stock Number	
Depth		Depth		Depth		Depth	
ALUMINUM	Al	ALUMINUM	Al	ALUMINUM	Al	ALUMINUM	Al
SILVER	Ag	SILVER	Ag	SILVER	Ag	SILVER	Ag
ARSENIC	As	ARSENIC	As	ARSENIC	As	ARSENIC	As
BORON	B	BORON	B	BORON	B	BORON	B
BARIUM	Ba	BARIUM	Ba	BARIUM	Ba	BARIUM	Ba
BERYLLIUM	Be	BERYLLIUM	Be	BERYLLIUM	Be	BERYLLIUM	Be
CADMIUM	Cd	CADMIUM	Cd	CADMIUM	Cd	CADMIUM	Cd
COBALT	Co	COBALT	Co	COBALT	Co	COBALT	Co
CHROMIUM	Cr	CHROMIUM	Cr	CHROMIUM	Cr	CHROMIUM	Cr
COPPER	Cu	COPPER	Cu	COPPER	Cu	COPPER	Cu
IRON	Fe	IRON	Fe	IRON	Fe	IRON	Fe
MERCURY	Hg	MERCURY	Hg	MERCURY	Hg	MERCURY	Hg
LITHIUM	Li	LITHIUM	Li	LITHIUM	Li	LITHIUM	Li
MANGANESE	Mn	MANGANESE	Mn	MANGANESE	Mn	MANGANESE	Mn
MOLYBDENUM	Mo	MOLYBDENUM	Mo	MOLYBDENUM	Mo	MOLYBDENUM	Mo
NICKEL	Ni	NICKEL	Ni	NICKEL	Ni	NICKEL	Ni
PHOSPHORUS	P	PHOSPHORUS	P	PHOSPHORUS	P	PHOSPHORUS	P
LEAD	Pb	LEAD	Pb	LEAD	Pb	LEAD	Pb
STRONTIUM	Sr	STRONTIUM	Sr	STRONTIUM	Sr	STRONTIUM	Sr
SELENIUM	Se	SELENIUM	Se	SELENIUM	Se	SELENIUM	Se
VANADIUM	V	VANADIUM	V	VANADIUM	V	VANADIUM	V
ZINC	Zn	ZINC	Zn	ZINC	Zn	ZINC	Zn
PARTICLE SIZE ANALYSIS		PARTICLE SIZE ANALYSIS		PARTICLE SIZE ANALYSIS		PARTICLE SIZE ANALYSIS	
Very Coarse Sand		Very Coarse Sand		Very Coarse Sand		Very Coarse Sand	
Coarse Sand		Coarse Sand		Coarse Sand		Coarse Sand	
Medium Sand		Medium Sand		Medium Sand		Medium Sand	
Fine Sand		Fine Sand		Fine Sand		Fine Sand	
Very Fine Sand		Very Fine Sand		Very Fine Sand		Very Fine Sand	
TOTAL SAND		TOTAL SAND		TOTAL SAND		TOTAL SAND	
SILT		SILT		SILT		SILT	
CLAY		CLAY		CLAY		CLAY	
TEXTURAL CLASS (LAB)		TEXTURAL CLASS (LAB)		TEXTURAL CLASS (LAB)		TEXTURAL CLASS (LAB)	
BULK DENSITY		BULK DENSITY		BULK DENSITY		BULK DENSITY	
HYDRAULIC CONDUCTIVITY		HYDRAULIC CONDUCTIVITY		HYDRAULIC CONDUCTIVITY		HYDRAULIC CONDUCTIVITY	
6th Hr.		6th Hr.		6th Hr.		6th Hr.	
24th Hr.		24th Hr.		24th Hr.		24th Hr.	
SETTLING VOLUME		SETTLING VOLUME		SETTLING VOLUME		SETTLING VOLUME	
MOISTURE RETENTION		MOISTURE RETENTION		MOISTURE RETENTION		MOISTURE RETENTION	
1/10 bar		1/10 bar		1/10 bar		1/10 bar	
15 bar		15 bar		15 bar		15 bar	
SOIL REACTION-pH		SOIL REACTION-pH		SOIL REACTION-pH		SOIL REACTION-pH	
Paste		Paste		Paste		Paste	
1:5 H <sub>2</sub> O		1:5 H <sub>2</sub> O		1:5 H <sub>2</sub> O		1:5 H <sub>2</sub> O	
1:2 0.01 M CaCl <sub>2</sub>		1:2 0.01 M CaCl <sub>2</sub>		1:2 0.01 M CaCl <sub>2</sub>		1:2 0.01 M CaCl <sub>2</sub>	
ORGANIC CARBON		ORGANIC CARBON		ORGANIC CARBON		ORGANIC CARBON	
AVAILABLE PHOSPHORUS		AVAILABLE PHOSPHORUS		AVAILABLE PHOSPHORUS		AVAILABLE PHOSPHORUS	
Ca CO <sub>3</sub> EQUIVALENT		Ca CO <sub>3</sub> EQUIVALENT		Ca CO <sub>3</sub> EQUIVALENT		Ca CO <sub>3</sub> EQUIVALENT	
GYPSUM REQUIREMENT		GYPSUM REQUIREMENT		GYPSUM REQUIREMENT		GYPSUM REQUIREMENT	
SATURATION EXTRACT		SATURATION EXTRACT		SATURATION EXTRACT		SATURATION EXTRACT	
Saturation Percentage		Saturation Percentage		Saturation Percentage		Saturation Percentage	
EC@ 25 C		EC@ 25 C		EC@ 25 C		EC@ 25 C	
Ca++		Ca++		Ca++		Ca++	
Mg++		Mg++		Mg++		Mg++	
Na+		Na+		Na+		Na+	
K+		K+		K+		K+	
CO <sub>3</sub> -		CO <sub>3</sub> -		CO <sub>3</sub> -		CO <sub>3</sub> -	
HCO <sub>3</sub> -		HCO <sub>3</sub> -		HCO <sub>3</sub> -		HCO <sub>3</sub> -	
Cl-		Cl-		Cl-		Cl-	
SO <sub>4</sub> -		SO <sub>4</sub> -		SO <sub>4</sub> -		SO <sub>4</sub> -	
NO <sub>3</sub> -		NO <sub>3</sub> -		NO <sub>3</sub> -		NO <sub>3</sub> -	
SAR		SAR		SAR		SAR	
Na		Na		Na		Na	
Ca+Mg		Ca+Mg		Ca+Mg		Ca+Mg	
1:5 EXTRACT		1:5 EXTRACT		1:5 EXTRACT		1:5 EXTRACT	
FC@ 25°C		FC@ 25°C		FC@ 25°C		FC@ 25°C	
Ca+Mg		Ca+Mg		Ca+Mg		Ca+Mg	
EXCHANGEABLE SODIUM		EXCHANGEABLE SODIUM		EXCHANGEABLE SODIUM		EXCHANGEABLE SODIUM	
ACIDITY		ACIDITY		ACIDITY		ACIDITY	
IN KCL exchange acidity		IN KCL exchange acidity		IN KCL exchange acidity		IN KCL exchange acidity	
Total		Total		Total		Total	
Al+++		Al+++		Al+++		Al+++	
CATION EXCHANGE CAPACITY		CATION EXCHANGE CAPACITY		CATION EXCHANGE CAPACITY		CATION EXCHANGE CAPACITY	
NaOAc@pH 8.2		NaOAc@pH 8.2		NaOAc@pH 8.2		NaOAc@pH 8.2	
BORON		BORON		BORON		BORON	

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Study Area: Pumpkin Creek Relief: \_\_\_\_\_ Stoniness: \_\_\_\_\_ Parent Material: \_\_\_\_\_  
Location, Sec.        Twp.        Range        Elevation: \_\_\_\_\_ Soil Series: \_\_\_\_\_  
Slope Aspect: \_\_\_\_\_ Drainage: \_\_\_\_\_ Soil Classification: \_\_\_\_\_  
Climate: \_\_\_\_\_ Ground Water: \_\_\_\_\_  
Land Use: \_\_\_\_\_ Land Form: \_\_\_\_\_ Profile Description By: \_\_\_\_\_ Date: \_\_\_\_\_

DETERMINATION		DATA	LABORATORY DESCRIPTION		DATA
Laboratory No. <u>Ninhow</u>			Laboratory Number		11,111
Depth			Soil Number		109-7
ALUMINUM	Al		PARTICLE SIZE ANALYSIS	(Ft)	130.0-142.5
SILVER	Ag		Very Coarse Sand	(percent)	
ARSENIC	As		Coarse Sand	(2.0-1.0 mm)	
BORON	B		Medium Sand	(1.0-0.5 mm)	
BARIUM	Ba		Fine Sand	(0.5-0.25 mm)	
BERYLLIUM	Be		Very Fine Sand	(0.25-0.10 mm)	
CADMIUM	Cd		TOTAL SAND	(0.10-0.05 mm)	
COBALT	Co		SILT	(2.0-0.05 mm)	
CHROMIUM	Cr		CLAY	(0.05-0.002 mm)	
COPPER	Cu		TEXTURAL CLASS (LAB)	(g/cm <sup>3</sup> )	
IRON	Fe		BULK DENSITY	(in/hr)	*1/3
MERCURY	Hg		HYDRAULIC CONDUCTIVITY		*1/2
LITHIUM	Li		6th Hr.		82
MANGANESE	Mn		24th Hr.		
MOLYBDENUM	Mo		SETTLING VOLUME	(ml)	
NICKEL	Ni		MOISTURE RETENTION	(percent)	
PHOSPHOROUS	P		1/10 bar		
LEAD	Pb		1/3 bar		
STRONTIUM	Sr		15 bar		
SELENIUM	Se		SOIL REACTION-pH		
VANADIUM	V		Paste		
ZINC	Zn		1:5 H <sub>2</sub> O		9.3
			1:2 0.01 M CaCl <sub>2</sub>		
			ORGANIC CARBON	(percent)	
			AVAILABLE PHOSPHORUS	(ppm)	
			Ca CO <sub>3</sub> EQUIVALENT	(percent)	
			GYPNUM REQUIREMENT	(me/100g)	
			SATURATION EXTRACT		
			Saturation Percentage		
			EC <sub>e</sub> @ 25 °C	(mmhos/cm)	2.6
			Ca++	(me/l)	
			Mg++	(me/l)	
			Na+	(me/l)	
			K+	(me/l)	
			CO <sub>3</sub> -	(me/l)	
			HCO <sub>3</sub> -	(me/l)	
			Cl-	(me/l)	
			SO <sub>4</sub> -	(me/l)	
			NO <sub>3</sub> -	(me/l)	
			SAR	(me/l)	
			Na	(me/100g)	
			Ca+Mg	(me/100g)	
			1:5 EXTRACT		
			FC <sub>s</sub> @ 25 °C	(mmhos/cm)	
			Ca+Mg	(me/l)	
			EXCHANGEABLE SODIUM		
			ACIDITY	(percent)	
			IN KCL exchange acidity		
			Total		
			Al+++	(me/100g)	
			CATION EXCHANGE CAPACITY	(me/100g)	
			NaOAc@pH 8.2	(me/100g)	
			BORON	(mg/l)	

\* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Study Area: Pumpkin Creek Relief: \_\_\_\_\_ Stoniness: \_\_\_\_\_ Parent Material: \_\_\_\_\_  
Location. Sec. \_\_\_\_\_ Twp. \_\_\_\_\_ Range \_\_\_\_\_ Elevation: \_\_\_\_\_ Soil Series: \_\_\_\_\_  
Slope Aspect: \_\_\_\_\_ Drainage: \_\_\_\_\_ Soil Classification: \_\_\_\_\_  
Climate: \_\_\_\_\_ Ground Water: \_\_\_\_\_  
Land Use: \_\_\_\_\_ Land Form: \_\_\_\_\_ Profile Description By: \_\_\_\_\_ Date: \_\_\_\_\_

DETERMINATION		DATA	
Laboratory Number			
Soil Number			
DEPTH			
Very Coarse Sand	(ft)	11,112	11,113
Coarse Sand	(percent)	11,114	11,115
Medium Sand	(1.0-0.5 mm)	110-2	110-3
Fine Sand	(0.5-0.25 mm)	110-4	110-5
Very Fine Sand	(0.25-0.10 mm)	110-6	110-7
TOTAL SAND	(0.10-0.05 mm)	0.0-15.5	27.0-42.0
SILT	(2.0-0.05 mm)	42.0-48.0	48.0-74.0
CLAY	(0.05-0.002 mm)		
TEXTURAL CLASS (LAB)			
BULK DENSITY	(g/cm <sup>3</sup> )		
HYDRAULIC CONDUCTIVITY	(in/hr)		
6th Hr.			
24th Hr.			
SETTLING VOLUME	(ml)		
MOISTURE RETENTION	(percent)		
1/10 bar			
1/3 bar			
SOIL REACTION-PH			
Paste			
1:5 H <sub>2</sub> O			
1:2 0.01 M CaCl <sub>2</sub>			
ORGANIC CARBON	(percent)		
AVAILABLE PHOSPHORUS	(ppm)		
Ca CO <sub>3</sub> EQUIVALENT	(percent)		
CYPSUM REQUIREMENT	(me/100g)		
SATURATION EXTRACT			
Saturation Percentage			
EC@25°C	(mmhos/cm)		
Ca++	(me/l)		
Mg++	(me/l)		
Na+	(me/l)		
K+	(me/l)		
CO <sub>3</sub> -	(me/l)		
HCO <sub>3</sub> -	(me/l)		
Cl-	(me/l)		
SO <sub>4</sub> -	(me/l)		
NO <sub>3</sub> -	(me/l)		
SAR	(me/l)		
Na	(me/l)		
Ca+Mg	(me/100g)		
1:5 EXTRACT			
FC@25°C	(mmhos/cm)		
Ca+Mg	(me/l)		
EXCHANGEABLE SODIUM	(percent)		
ACIDITY			
IN KCL exchange acidity			
- Total	(me/100g)		
Al+++	(me/100g)		
CATION EXCHANGE CAPACITY	(me/100g)		
NaOAc@pH 8.2	(me/100g)		
BORON	(mg/l)		



Suitability of Bedrock Material for Use as Plant Media in Revegetation  
Pumpkin Creek Study Area

Bedrock Core No. 76-101

<u>Depth</u>	<u>Type</u>	<u>Suitability</u>	<u>Deficiency</u>
0-12.8'	Sish	Unsuitable	Saline
12.8-34.5'	Sish	Unsuitable	Clay
34.5-40.5'	SiSs	Unsuitable*	Sodic
40.5-57.5'	Sh	Unsuitable	Clay-Sodic
57.5-58.5'	Sish	**	
58.5-71.5'	SiSs,Sist	**	
71.5-72.4'	Sist	**	
72.4-74.5'	SiSs	**	
74.5-95.5'	Sh	Unsuitable	Clay-Sodic
95.5-103.6'	C-Si Ss	Unsuitable	Clay-Sodic
103.6-119.1'	Sh	Unsuitable	Clay-Sodic
119.1-125.0'	SiSs	Limited	Saline
125.0-126.5'	Sh	Unsuitable	Carbonaceous
126.5-134.0'	Sish,Ss	Unsuitable	Sodic
134.0-141.5'	Sh	Unsuitable	Sodic
141.5-142.2'	Cbsh	Unsuitable	Carbonaceous
142.2-154.5'	Sish	Unsuitable	Clay-Sodic
154.5-170.8'	C Sist	Unsuitable	Sodic
170.8-173.9'	CbSh	Unsuitable	Carbonaceous
173.9-178.4'	Coal	Unsuitable	Carbonaceous
178.4-204.0'	Sh,Ss	Unsuitable	Clay-Sodic
204.0-232.3'	Sish,SiSs	Unsuitable	Sodic
232.3-265.9'	Sh,SiSs	Unsuitable	Sodic
265.9-299.0'	Coal	Unsuitable	Carbonaceous
299.0-314.5'	Sish	Unsuitable	Sodic

Legend

Ss - Sandstone  
SiSs - Silty sandstone  
Css - Clayey sandstone  
Sist - Siltstone  
S Sist - Sandy siltstone

C Sist - Clayey siltstone  
Sh - Shale  
Ssh - Sandy shale  
Sish - Silty shale  
Cbsh - Carbonaceous shale

Le St - Limestone

\* Suitability determination based on screenable laboratory data only - conductivity, pH, hydraulic conductivity, and settling volume.

\*\* Laboratory data unavailable - no sample obtained.

Suitability of Bedrock Material for Use as Plant Media in Revegetation  
Pumpkin Creek Study Area

Bedrock Core No. 77-102

<u>Depth</u>	<u>Type</u>	<u>Suitability</u>	<u>Deficiency</u>
0-11.5'	Ss,Sh,S Sist	**	
11.5-17.0'	S Sist	Limited	Slow Perm.
17.0-24.8'	CbSh,Coal	Unsuitable	Carbonaceous
24.8-44.2'	Sh	Unsuitable	Clay-Sodic
44.2-66.0'	SiSs	Unsuitable	Sodic
66.0-82.5'	SiSs	Unsuitable	Sodic
82.5-88.5'	Ssh	Unsuitable	Clay-Sodic
88.5-121.0'	Coal	Unsuitable	Carbonaceous
121.0-140.0'	SiSh,Ssh	Unsuitable	Clay-Sodic
140.0-154.0'	SiSh,Ssh	Unsuitable	Sodic

\* Suitability determination based on screenable laboratory data only -  
conductivity, pH, hydraulic conductivity, and settling volume.

\*\* Laboratory data unavailable - no sample obtained.

Suitability of Bedrock Material for Use as Plant Media in Revegetation  
Pumpkin Creek Study Area

Bedrock Core No. 77-103

<u>Depth</u>	<u>Type</u>	<u>Suitability</u>	<u>Deficiency</u>
0-11.0'	SiSs,Sh	Suitable	
11.0-29.5'	S Sist,Sh	Unsuitable	Saline-Sodic
29.5-40.7'	C Sist	Unsuitable	Saline-Sodic
40.7-56.2'	SiSs	Unsuitable	Sodic
56.2-68.0'	SiSs	Limited	Slow Perm.
68.0-78.3'	Ssh,Sh	Limited	Slow Perm.
78.3-86.3'	Coal,CbSh	Unsuitable	Carbonaceous
86.3-94.5'	Ssh	Unsuitable	Clay-Sodic
94.5-115.0'	SiSs-Css	Unsuitable	Sodic
115.0-131.0'	Ssh-Css	Unsuitable	Sodic
131.0-145.0'	Ssh	Unsuitable	Sodic
145.0-159.8'	Ssh	Unsuitable	Sodic
159.8-191.0'	Coal	Unsuitable	Carbonaceous
191.0-204.5'	SiSs-Css	Unsuitable	Sodic

Suitability of Bedrock Material for Use as Plant Media in Revegetation  
Pumpkin Creek Study Area

Bedrock Core No. 77-104

<u>Depth</u>	<u>Type</u>	<u>Suitability</u>	<u>Deficiency</u>
0-12.0'	SiSs	Unsuitable	Saline
12.0-18.0'	Sh	Unsuitable	Sodic
18.0-20.0'	Le St	Unsuitable	Indurated
20.0-26.5'	Ss,Sh	Unsuitable	Sodic
26.5-35.5'	Css,Cbsh	Unsuitable	Sodic-Carbonaceous
35.5-37.0'	Coal	Unsuitable	Carbonaceous
37.0-55.2'	Ss,Ssh,Css	Unsuitable	Sodic
55.2-80.0'	Ssh	Unsuitable	Clay-Sodic
80.0-103.5'	Ssh	Unsuitable	Clay-Sodic
103.5-113.0'	Css-Sh	Unsuitable	Sodic
113.0-113.5'	Coal	Unsuitable	Carbonaceous
113.5-119.5'	Sh	Unsuitable	Sodic
119.5-120.5'	Coal	Unsuitable	Carbonaceous
120.5-129.9'	Css,Sist	Unsuitable	Sodic
129.9-144.5'	Ssh	Limited	Slow Perm.
144.5-155.5'	Sh	Unsuitable	Sodic
155.5-156.7'	Coal	Unsuitable	Carbonaceous
156.7-167.0'	Ssh,Css	Unsuitable	Sodic
167.0-167.5'	Coal	Unsuitable	Carbonaceous
167.5-179.5'	Cbsh,Css	Unsuitable	Sodic-Carbonaceous
179.5-202.7'	Sh, Ss,Ssh	Unsuitable	Sodic
202.7-215.5'	Coal	Unsuitable	Carbonaceous
215.5-225.0'	Sh,SiSs	Limited	Slow Perm.
225.0-244.0'	SiSs	Unsuitable	Sodic
244.0-259.5'	Sh,S Sist	Unsuitable	Sodic
259.5-272.0'	Coal	Unsuitable	Carbonaceous
272.0-289.5'	S-C Sist	Unsuitable	Sodic

Suitability of Bedrock Material for Use as Plant Media in Revegetation  
Pumpkin Creek Study Area

Bedrock Core No. 77-105

<u>Depth</u>	<u>Type</u>	<u>Suitability</u>	<u>Deficiency</u>
0-15.8'	Css,Sh,Ss	Limited	Clay-Slow Perm.
15.8-26.8'	Sh,Css,Cbsh	Suitable	
26.8-40.0'	Ss	Suitable	
40.0-50.5'	Sh,Sh,Ssh	Unsuitable	Sodic
50.5-62.0'	Ss	Suitable	
62.0-77.0'	S Sist	Limited	Sodic-Slow Perm.
77.0-94.5'	Sish,Ss,Sh	Unsuitable	Sodic
94.5-108.5'	Sh	Unsuitable	Sodic
108.5-109.0'	Coal	Unsuitable	Carbonaceous
109.0-130.0'	Ssh	Unsuitable	Sodic
130.0-142.0'	Ssh	Unsuitable	Sodic
142.0-161.2'	Css,Ssh	Unsuitable	Sodic
161.2-174.0'	Css	Unsuitable	Sodic
174.0-189.5'	Sh	Unsuitable	Sodic
189.5-190.0'	Coal	Unsuitable	Carbonaceous
190.0-198.0'	Sh,Css	Unsuitable	Sodic
198.0-206.0'	Sh	Unsuitable	Sodic
206.0-222.5'	Coal,Cbsh,Sist	Unsuitable	Carbonaceous
222.5-236.3'	Coal	Unsuitable	Carbonaceous
236.3-251.5'	S-C Cist,Ss	Limited	Sodic-Slow Perm.

Suitability of Bedrock Material for Use as Plant Media in Revegetation  
Pumpkin Creek Study Area

Bedrock Core No. 77-106

<u>Depth</u>	<u>Type</u>	<u>Suitability</u>	<u>Deficiency</u>
0-18.4'	Sist,Sh,Css	Unsuitable	Clay-Sodic
18.4-36.0'	S Sist	Unsuitable	Sodic
36.0-59.5'	Ss	Unsuitable	Sodic
59.5-74.0'	Ssh,Ss,Sh	Unsuitable	Sodic
74.0-76.5'	Ss	Unsuitable	Sodic
76.5-95.0'	Sh	Unsuitable	Sodic
95.0-104.5'	Ss,Ssh	Unsuitable	Sodic
104.5-116.3'	SiSs	Unsuitable	Sodic
116.3-123.5'	Sh	Unsuitable	Sodic
123.5-152.8'	Coal	Unsuitable	Carbonaceous
152.8-164.0'	SiSs	Unsuitable	Sodic

Suitability of Bedrock Material for Use as Plant Media in Revegetation  
Pumpkin Creek Study Area

Bedrock Core No. 77-107

<u>Depth</u>	<u>Type</u>	<u>Suitability</u>	<u>Deficiency</u>
0-14.5'	Ssh,SiSs	Unsuitable	Saline-Sodic
14.5-32.0'	S Sist	Limited	Slow Perm.
32.8-39.0'	Sh, S Sist	Limited	Slow Perm.
39.0-59.0'	SiSs,S Sist	Limited	Slow Perm.
59.0-64.8'	Coal,Cbsh	Unsuitable	Carbonaceous
64.8-74.5'	Ssh	Unsuitable	Sodic
74.5-88.0'	Ssh,Cbsh	Unsuitable	Clay-Sodic
88.0-117.8'	Sh	Unsuitable	Clay-Sodic
117.8-131.5'	Coal	Unsuitable	Carbonaceous
131.5-132.4'	Sh	Unsuitable	Clay-Sodic
132.4-151.8'	Coal	Unsuitable	Carbonaceous
151.8-164.5'	S Sist,SiSs	Unsuitable	Sodic

Suitability of Bedrock Material for Use as Plant Media in Revegetation  
Pumpkin Creek Study Area

Bedrock Core No. 77-108

<u>Depth</u>	<u>Type</u>	<u>Suitability</u>	<u>Deficiency</u>
0-20.0'	Sh, SiSs	Limited	Clay-Slow Perm.
20.0-40.0'	Ssh	Unsuitable	Sodic
40.0-65.0'	Ssh	Unsuitable	Sodic
65.0-87.8'	Ssh, Sh	Unsuitable	Sodic
87.8-118.7'	Coal	Unsuitable	Carbonaceous
118.7-134.0'	Sh, Ss	Unsuitable	Sodic

Suitability of Bedrock Material for Use as Plant Media in Revegetation  
Pumpkin Creek Study Area

Bedrock Core No. 77-109

<u>Depth</u>	<u>Type</u>	<u>Suitability*</u>	<u>Deficiency</u>
0-15.0'	Sh,Cbsh	Limited	Salinity-Carbonaceous
15.0-17.5'	Coal	Unsuitable	Carbonaceous
17.5-34.0'	Cbsh,Ssh	Limited	Slow Perm.-Carbonaceous
34.0-50.2'	Css,Sh	Unsuitable	Sodic
50.2-62.0'	Ss,Ssh,Sh	Unsuitable	Sodic
62.0-82.5'	Ss,Sh	Unsuitable	Sodic
82.5-116.3'	Coal	Unsuitable	Carbonaceous
116.3-130.0'	S Sist	Unsuitable	Sodic
130.0-142.5'	S Sist	Unsuitable	Sodic

\* Suitability determination based on screenable laboratory data only - conductivity, pH, hydraulic conductivity, and settling volume.

Suitability of Bedrock Material for Use as Plant Media in Revegetation  
Pumpkin Creek Study Area

Bedrock Core No. 77-110

<u>Depth</u>	<u>Type</u>	<u>Suitability*</u>	<u>Deficiency</u>
0-15.5'	Sist	Limited	Sodic-Slow Perm.
15.5-27.0'	Coal,Cbsh	Unsuitable	Carbonaceous
27.0-42.0'	Css	Unsuitable	Sodic
42.0-48.0'	Ssh	Unsuitable	Sodic
48.0-74.0'	Css,Ssh	Unsuitable	Sodic
74.0-88.8'	Css,Cbsh	Unsuitable	Sodic-Carbonaceous
88.8-119.5'	Coal	Unsuitable	Carbonaceous
119.5-134.0'	Sist,SiSs	Unsuitable	Sodic

\* Suitability determination based on screenable laboratory data only -  
conductivity, pH, hydraulic conductivity, and settling volume.

Established Series  
Rev. AJC  
1/77

ARVADA SERIES

The Arvada series consists of deep, well drained soils that formed in material mainly from sedimentary rocks. Arvada soils are on uplands or alluvial fans and have slopes of 0 to 10 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 46°F.

Taxonomic Class: Fine, montmorillonitic, mesic Ustollic Natrargids.

Typical Pedon: Arvada fine sandy loam - grassland. (Colors are for dry soil unless otherwise noted.)

A2--0 to 4 inches; light gray (10YR 7/2) fine sandy loam, grayish brown (10YR 5/2) moist; moderate very thin platy structure that parts to moderate fine granular; soft, very friable; vesicular; noncalcareous; mildly alkaline (pH 7.8); abrupt smooth boundary. (0 to 6 inches thick)

B25--4 to 14 inches; brown (10YR 5/3) clay, dark brown (10YR 4/3) moist; moderate medium columnar structure that parts to moderate medium angular blocky; extremely hard, firm, very plastic; moderate continuous wax-like coatings on faces of peds and in root channels; strongly alkaline (pH 9.2); ESP 20 percent; clear smooth boundary. (8 to 14 inches thick)

B3casa--14 to 20 inches; brown (10YR 5/3) heavy clay loam, dark brown (10YR 4/3) moist; weak medium subangular blocky structure; extremely hard, firm, very plastic; weak visible accumulation of calcium carbonate and other salts as crystals, in concretions, and in thin seams and streaks; few thin glossy patches on faces of peds; some wax-like fillings in root channels; calcareous; very strongly alkaline (pH 9.0); 20 percent exchangeable sodium; gradual smooth boundary. (5 to 10 inches thick)

Ccasa--20 to 60 inches; light yellowish brown (2.5Y 6/3) heavy clay loam, light olive brown (2.5Y 5/3) moist; massive; hard, friable; plastic; moderate accumulation of visible calcium carbonate and other soluble salts as crystals, in thin seams and streaks, and in concretions; strongly alkaline (pH 8.8); 20 percent exchangeable sodium.

Type Location: Sheridan County, Wyoming; 650 feet south and 200 feet west of the NE corner of section 29, T.55N., R.78W.

Range in Characteristics: Depth to calcareous material ranges from 0 to 12 inches, thickness of solum ranges from 15 to 30 inches. Organic carbon in the upper 15 inches averages more than 0.6 percent. Thin A1 horizons occur in some pedons. Light colored platy A2 horizons are generally present but are absent in some pedons. Gravel is typically less than 5 percent and ranges from 0 to 15 percent. Mean annual soil temperature ranges from 47° to 58°F., the mean summer soil temperature ranges from 59° to 78°F. Length of time the soil temperature at 20 inches exceeds 41°F. normally ranges from 230 to 305 days. Length of time (cumulative) the soil is moist in some part of the moisture control section while the soil temperature at 20 inches is above 41°F. normally ranges from 56 days to 152 days, but in most years, it should not be less than one-fourth or more than one-half of the time the soil is above 41°F.

The A horizon has hue of 2.5Y or 10YR, value of 5 or 6 dry or 4 or 5 moist, and chroma of 2 through 4. It ranges from mildly to strongly alkaline. Consistence is soft or slightly hard. The B2t horizon has hue of 2.5Y through 7.5YR, value of 5 or 6 dry, 4 or 5 moist and chroma of 2 through 4. It is typically clay, but clay ranges from 35 to 60 percent, silt from 10 to 50 percent, and sand from 5 to 50 percent. This horizon ranges from strongly to very strongly alkaline (pH 8.8 to 10.0) and has from 15 to 34 percent exchangeable sodium. Its cation exchange capacity ranges from 70 to 100 miliequivalents per 100 grams of clay.

The C horizon has hue of 2.5Y through 7.5YR. It ranges from strongly alkaline to very strongly alkaline (pH 8.6 to 10.0) and contains 4 to 12 percent calcium carbonate equivalent. ESP typically ranges from 10 to 30 percent, but generally decreases with increasing depth.

Competing Series: These are the Allentine, Bone, Deertrail, Gilt Edge, and Winnett series. Allentine and Gilt Edge soils have less than 15 percent exchangeable Na in the B2t horizon. Bone soils have combined thickness of the A2 and Bt horizons of less than 5 inches. Deertrail soils have less than 15 percent exchangeable sodium in the upper part of the B2t horizon. Winnett soils have a paralithic contact within 40 inches of the surface and have A horizons 5 to 8 inches thick.

Geographic Setting: The Arvada soils are on uplands and alluvial fans. Gradients range from 0 to 10 percent. The soils formed in thick, medium to moderately fine textured sediments usually derived from sedimentary rocks or pediments of mixed origin. At the type location, the average annual precipitation is 14 inches, with peak periods of precipitation occurring during the spring and summer. The mean annual temperature is about 46°F., and the mean summer temperature is 67°F. The frost-free season is 100 to 130 days.

Arvada Series

Geographically Associated Soils: These are the Absted, Renohill and Ulm soils. Absted soils have less than 15 percent sodium in the upper part of the argillic horizon. Renohill and Ulm soils lack natric horizons.

Drainage and Permeability: Well-drained; medium to rapid runoff; very slow permeability.

Use and Vegetation: These soils are generally used as native pastureland. Native vegetation is principally short grass, weeds, and cactus, with common barren areas.

Distribution and Extent: Eastern Wyoming, and Montana. The series is of moderate extent.

Series Established: Sheridan County, Wyoming, 1932.

Remarks: These soils frequently occur in a complex pattern with other soils.

National Cooperative Soil Survey  
U.S.A.

Established Series  
Rev. CAM  
3/71

### BONE SERIES

The Bone series is a member of the fine, montmorillonitic (calcareous), mesic family of Ustic Torriorthents. Typically, Bone soils have white massive surface crusts vesicular loam A2 horizons, light brownish gray columnar clay B2t horizons about 3 inches thick and pale olive salt-flecked, granular clay B3 horizons, grading to pale olive calcareous clay C horizons.

Typifying Pedon: Bone silty clay - native cover  
(Colors are for dry soil unless otherwise noted.)

- A2 0-1"--White (2.5Y 8/2) loam, grayish brown (2.5Y 5/2) moist; massive; hard, friable, slightly sticky, slightly plastic; silt and sand grains are uncoated and unstained; many fine vesicles; noneffervescent; abrupt smooth boundary. (1/2 to 2 inches thick)
- B2t 1-3"--Light brownish gray (2.5Y 6/2) light silty clay, olive brown (2.5Y 4/3) moist; weak coarse columnar structure that separates to strong very fine angular blocks; hard, firm, sticky, plastic; distinct clay films on all faces of peds; noneffervescent; moderately alkaline; clear boundary. (1 to 3 inches thick)
- B3ca 3-12"--Pale olive (5Y 6/3) clay, olive (5Y 5/4) moist; moderate coarse granular structure; hard, firm, very sticky, very plastic; many seams and nests of gypsum and salts; moderate effervescence; moderately alkaline; gradual boundary. (6 to 15 inches thick)
- C1 12-23"--Pale olive (5Y 6/3) clay, olive (5Y 5/4) moist; moderate medium and fine blocky structure; very hard, firm, very sticky, very plastic; few seams and nests of salt and gypsum; moderate effervescence; very strongly alkaline; gradual boundary. (6 to 16 inches thick)
- C2 23-65"--Pale olive (5Y 6/3) clay, olive (5Y 5/4) moist; massive; very hard, very firm, very sticky, very plastic; few seams and nests of salt and gypsum; moderate effervescence; very strongly alkaline.

Type Location: Yellowstone County, Montana; 1,400 feet south and 400 feet east of NW corner of section 21, T.3N., R.24E.

Range in Characteristics: The noncalcareous part of the solum and depth to the base of the B2t horizon range from 2 to 5 inches. Mean annual soil temperature ranges from 47° to 53°F., and average summer soil temperature ranges from 60° to 65°F. Hue of the soil is 10YR through 5Y. The A2 horizon has value of 6 or 7 dry and 4 through 6 moist. White vesicular massive crusts 1/8 to 1/2 inch thick form on the surface of dry cultivated fields. Where the A2 horizon is thicker than 1 inch, it has thick platy structure. The B2t horizon has value of 5 or 6 dry, 3 or 4 moist and chroma of 2 through 4. It has strong fine columnar, strong fine blocky or strong coarse granular structure. The amount of visible gypsum and salt decreases below a depth of 10 to 20 inches. Soluble salt concentrations range from 2 to 3 percent. The B3ca horizon is granular or blocky and has clay films on peds in some pedons.

Competing Series and their Differentiae: These are the Arvada, Gaynor, Limon (tentative), Nobe, Petrie, Sage and Seebree series. Arvada soils have B2t horizons more than 8 inches thick extending to depths of about 14 inches. Seebree soils have an alkali- and lime-cemented hardpan. Sage soils lack B2t horizons and have salic horizons and mottled colors. Nobe soils have summer temperatures ranging from 55° to 59°F. Gaynor, Limon and Petrie soils lack salic horizons and crusted surfaces. In addition, the Gaynor and Limon soils are moderately alkaline throughout and Gaynor soils have shale bedrock at depths of less than 40 inches.

Setting: Bone soils are in level to sloping positions on uplands and in valleys. They formed in clayey transported or residual materials that are saline and alkali. The climate is cool semiarid with a mean annual temperature of 44 °to 48°F., mean summer temperature ranging from 60° to 70°F., and a mean annual precipitation ranging from 6 to 14 inches.

**Bone Series**

Principal Associated Soils: These are the competing Arvada soils. The pattern of their association is complex with the diameter of areas of Bone soils measured in a few tens of feet.

Drainage and Permeability: Infiltration and permeability rates are very slow in this soil. Water saturated substrata layers are of short period duration except where water table develops under irrigation.

Use and Vegetation: In native grasslands, areas of Bone soils are barren or have a sparse cover of alkali tolerant forbs, greasewood, saltgrass, and western wheatgrass. Areas under cultivation remain barren or produce low yields of grain and alfalfa under dryland or irrigated agriculture.

Distribution and Extent: Semiarid regions of the Northern Great Plains. Bone soils are extensive in their collective areas, but locally they are inextensive.

Series Established: Big Horn County (Big Horn Area), Montana, 1970.

Remarks: The Bone soils were formerly classified as Solonchak soils.

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BEW SERIES

The Bew series is a member of the fine, montmorillonitic, mesic family of Ustertic Haplargids. Typically, Bew soils have grayish brown clay Ap horizons and grayish brown grading to light brownish gray prismatic clay B2t horizons with distinct varnish-like films on peds and on walls of pores. Nodules and films of segregated lime appear in the lower B and upper C horizons of calcareous clay grading to calcareous clay loam.

Typifying Pedon: Bew clay - cultivated  
(Colors are for dry soil unless otherwise noted.)

- Ap 0-6"--Grayish brown (2.5Y 5/2) clay, dark grayish brown (2.5Y 4/2) moist; moderate medium and fine granular structure; hard, firm, very sticky, very plastic; neutral (pH 6.8); clear smooth boundary.
- B2t 6-11"--Grayish brown (2.5Y 5/2) clay, olive brown (2.5Y 4/3) moist; moderate medium prismatic structure that separates to moderate medium and fine blocks; very hard, very firm, very sticky, very plastic; distinct film on faces of peds and walls of pores; neutral (pH 7.1); clear wavy boundary.
- B2t 11-17"--Light brownish gray (2.5Y 6/2) clay, dark grayish brown (2.5Y 4/2) moist; weak medium blocky structure; very hard, very firm, very sticky, very plastic; distinct film on faces of peds and on walls of pores; weak effervescence, with few lime segregations; moderately alkaline; gradual wavy boundary. (B2t horizon 7 to 20 inches thick)
- B3ca 17-22"--Light brownish gray (2.5Y 6/2) clay, grayish brown (2.5Y 5/2) moist; weak medium blocky structure; very hard, very firm, very sticky, very plastic; moderate effervescence with few masses of lime; moderately alkaline; gradual wavy boundary. (0 to 7 inches thick)
- Clca 22-32"--Olive gray (5Y 5/2) clay, olive (5Y 4/3) moist; massive; very hard, very firm, very sticky, very plastic; strong effervescence; common threads and fine masses of lime; moderately alkaline; gradual wavy boundary. (5 to 6 inches thick)
- C2 32-60"--Olive gray (5Y 5/2) clay loam, olive (5Y 4/3) moist; massive; very hard, firm, very sticky, very plastic; moderately alkaline; strong effervescence; few small pebbles increasing to 30 percent in the lower part.

Type Location: Yellowstone County, Montana; 930 feet west and 33 feet south of NE corner of sec. 32, T.2N., R.25E.

Range in Characteristics: The noncalcareous part of the solum ranges from 11 to 20 inches thick. The Bew soils have clay textures to depths of 30 or more inches. The clay is of expanding type with exchange capacity ranging from 50 to 70 millequivalents per 100 grams of lime-free clay. Organic matter averages 2 percent in the upper 15 inches. The soils are usually dry when not frozen unless they are irrigated. They have mean annual soil temperature ranging from 48° to 54°F. Hue is 10YR or 2.5Y in the solum and 2.5Y or 5Y in substratum horizons. Chroma is 2 or 3. The Ap horizon has value of 5 or 6 dry. The 3- to 5-inch thick clay loam Al horizon has value of 6 dry and 4 moist. The upper few inches of the B2t horizon has value of 4 or 5 coated and 5 crushed, and 3 or 4 moist, coated or crushed. The B2t horizon has 50 to 60 percent clay, and has 10 to 15 percent more clay than the Ap horizon and from 5 to 10 percent more clay than in the upper C horizon. It has moderate to strong prismatic or blocky structure that separates to fine blocks. The Cca horizon has few to common threads and masses of segregated lime. Contrasting strata of transported material or of shale occur below depths of 40 inches in some pedons.

Competing Series and their Differentiae: These are the Archuleta, Arnhart, Baca, Big Horn, Briggsdale, Hesper, Hinman, Malposa, Renohill, Thurlow and Ulm series. Archuleta soils have less than 15 percent fine or coarser sand in the B2t and C horizons and have 35 to 50 percent clay in the B2t horizon. Arnhart soils have CEC of 150 to 300 millequivalents per 100 grams of clay and have less than 50 percent clay in the B2t horizon. Baca, Hesper, Renohill, Thurlow and Ulm soils have 35 to 50 percent clay in the B2t horizon. In addition, Renohill soils have shale bedrock at depth of about 30 inches and Hesper soils have silt loam C horizons. Big horn and Briggsdale soils have an abrupt boundary between the A horizons and the clay B2t horizons. Hinman soils have less than one percent organic matter in the upper 15 inches of the pedon. Malposa soils have mixed clay types with less than 50 percent cation exchange capacity and have sandstone or shale bedrock.

Setting: The Bew soils are on uplands and in valleys on deep calcareous clay materials. The climate is cool semiarid with mean annual temperatures of 45° to 50°F.; mean summer temperatures of 65° to 70°F.; and average annual rainfall of 8 to 14 inches.

**Bew Series**

Principal Associated Soils: These are the Allentine, ~~Galata~~ Galata and Kyle soils and the competing Thurlow soils. Allentine and Galata soils have natric horizons and have much gray silt coating peds in the epipedon and in the Galata soils this continues into the upper part of the argillic horizon. Kyle soils lack argillic horizons.

Drainage and Permeability: Well-drained; slow permeability.

Use and Vegetation: Used primarily for irrigated and nonirrigated cropland. Native vegetation is mainly western wheatgrass, blue grama and sagebrush.

Distribution and Extent: Throughout southeastern Montana. It is moderately extensive.

Series Established: Treasure County, Montana, 1963.

Remarks: The Bew soils were formerly classified as Brown soils.

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CABBA SERIES

The Cabba series consists of well drained soils that formed in material weathered from soft sedimentary rock and have sedimentary beds at depths of 8 to 20 inches. Cabba soils are on uplands and are moderately sloping to very steep. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 45°F.

Taxonomic Class: Loamy, mixed (calcareous), frigid, shallow Typic Ustorthents.

Typical Pedon: Cabba cobbly clay loam, native grassland. (Colors are for dry soil unless otherwise noted.)

A1--0 to 2 inches; grayish brown (2.5Y 5/2) cobbly clay loam, grayish brown (2.5Y 4/2) moist; moderate fine crumb structure; slightly hard, friable, slightly sticky and slightly plastic; many fine roots and pores; 15 to 20 percent cobbles, gravel and stones; neutral (pH 7.3); gradual wavy boundary. (2 to 5 inches thick)

AC--2 to 7 inches; grayish brown (2.5Y 5/2) gravelly light clay loam, dark grayish brown (2.5Y 4/2) moist; moderate very fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; 20 percent pebbles; many fine roots and pores; neutral (pH 7.3); gradual wavy boundary. (2 to 10 inches thick)

C1--7 to 18 inches; very pale brown (10YR 7/2) gravelly loam, grayish brown (10YR 5/2) moist; massive; evidence of rock structure in small fragments of weakly consolidated siltstone; slightly hard, friable, nonsticky and slightly plastic; many fine roots and pores; 20 percent pebbles; slightly effervescent; coatings of lime on soft rock fragments; clear wavy boundary. (6 to 15 inches thick)

C2--18 to 60 inches; light gray (10YR 7/2) soft sedimentary bedrock, grayish brown (10YR 5/2) moist; can be chipped out only with a sharp instrument when dry but softens quickly on soaking in water, and becomes material that rubs to a loam texture; roots in cracks and some roots through plates; massive rock; mildly alkaline (pH 7.8.)

Type Location: Granite County, Montana; 1000 feet north and 1500 feet east of the southwest corner of section 35, 5.10N., R.12W.

Range in Characteristics: Depth to sedimentary beds is 8 to 20 inches. Mean annual soil temperature ranges from 40° to 47°F. The hue is 10YR or 2.5Y. Rock fragments range from 0 to 35 percent and are mainly of gravel size.

The A horizon has hue of 10YR or 2.5Y, value of 5 or 6 dry, 3 or 4 moist, and chroma of 1 or 2. It ranges from fine sandy loam through silt loam.

The C horizon has hue of 10YR through 5Y, value of 5 through 8 dry, 4 through 7 moist, and chroma of 1 through 3. It is loam, silt loam, silty clay loam or light clay loam and has 20 to 35 percent clay. The underlying sedimentary beds rub to silt loam or loam. This horizon is mildly or moderately alkaline.

Competing Series: These are the Abac and Cohagen series in the same family and the related Cabbart, Kuro, Midway and Wayden series. Abac soils have hue of 5YR or redder. Cabbart soils have an aridic moisture regime that borders on an ustic regime. Cohagen soils have sandy loam C horizons. Kuro soils contain 36 to 45 percent clay. Midway soils have soil temperature warmer than 47°F. Wayden soils have 36 to 50 percent clay.

Geographic Setting: Cabba soils are moderately sloping to very steep and are on uplands at elevations of 2000 to 4800 feet. They formed in material weathered from 12 to 19 inches with areas receiving less than 14 inches having cooler temperatures and lower evaporation. Most of the precipitation falls in the spring and early summer. Mean annual temperature ranges from 41° to 45°F. The (32°F.) growing season is 90 to 135 days.

Geographically Associated Soils: These are the Barvon, Campspass, Farland, Judith, Ringling, Shane and Thebo soils. Barvon soils have a mollic epipedon and are 20 to 40 inches deep to siltstone. Campspass and Farland soils have argillic horizons. Judith soils have a calcareous horizon immediately beneath the mollic epipedon. Ringling soils are fragmental. Shane soils contain more than 60 percent clay. Thebo soils contain more than 35 percent clay.

Drainage and Permeability: Well drained; moderate permeability.

Use and Vegetation: Used for rangeland. Native plants are bluebunch wheatgrass, little bluestem, needleandthread, western wheatgrass, green needlegrass, annual, and low-density stands of ponderosa pine.

Cabba Series

Distribution and Extent: Widely distributed in Montana. Cabba soils are of moderate extent.

Series Established: Granite County, Montana, 1969.

Remarks: The nature of the sedimentary beds is currently under study. The classification of the series may need to be changed if these soils lack a paralithic contact at shallow depth.

National Cooperative Soil Survey  
U. S. A.

Established Series  
Rev. RLM/CAM  
5/71

## CUSHMAN SERIES

The Cushman series is a member of the fine-loamy, mixed, mesic family of Ustollic Haplargids. Typically, Cushman soils have noncalcareous solums about 7 inches thick with grayish brown loam A1 horizons, brown prismatic light clay loam B2t horizons with dark brown coatings on prisms, pale brown light clay loam B3 horizons with small white masses of segregated lime, and light brownish gray Cca horizons resting on interbedded shale and sandstone at depths of about 24 inches.

Typifying Pedon: Cushman loam - native grass  
(Colors are of dry soil unless otherwise noted.)

- A1 -- 0-2" -- Grayish brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) moist; weak fine granular structure; soft, very friable, slightly sticky, slightly plastic; neutral (pH 7.0); clear boundary. (1 to 3 inches thick)
- B2t -- 2-7" -- Brown (10YR 5/3) light clay loam, dark brown (10YR 4/3) moist; coated dark brown (10YR 4/3), dark brown (10YR 3/3) moist; moderate medium prismatic structure; hard, friable, slightly sticky, slightly plastic; thin clay films and clay bridging mineral grains; neutral (pH 7.0); clear boundary. (4 to 7 inches thick)
- B3ca -- 7-12" -- Pale brown (10YR 6/3) light clay loam, brown (10YR 5/3) moist; moderate medium prismatic structure; hard, friable, slightly sticky, slightly plastic; moderate effervescence with common soft masses or nodules of segregated lime; gradual boundary. (4 to 6 inches thick)
- Cca -- 12-24" -- Light brownish gray (2.5Y 6/2) loam, light olive brown (2.5Y 5/3) moist; weak coarse prismatic structure grading to massive; hard, friable; moderate effervescence with common nodules of lime; few sandstone and shale fragments; abrupt boundary. (10 to 30 inches thick)
- C2 -- 24-30" -- Olive colored interbedded loam shales and sandstone.

Type Location: Treasure County, Montana; 250 feet south and 10 feet west of NE corner of sec. 6, T. 7 N., R. 34 E.

Range in Characteristics: The Cushman soils are usually dry unless irrigated, but are moist in some part above 12 inches more than half the time. The average annual soil temperature is 47° to 53°F. The noncalcareous part of the solum is 6 to 10 inches thick. Depth to bedrock is 20 to 40 inches. Hue is 2.5Y or 10YR. The cultivated soil has Ap, Bca, Cca, C2 horizon sequence in some pedons with the Ap horizon having value of 5 or 5.5 dry and 3.5 or 4 moist, and chroma of 2 or 3. The B2t horizon has from 25 to 30 percent clay with 5 to 10 percent more clay than in A1 horizon. The Bca horizon has redder hue than the underlying C horizons. The Cca horizon is distinct but is not a calcic horizon.

Competing Series and their Differentiae: These are the Clovis, Fort Collins, Fruita, Hagerman, Los Alamos, Mack, Mesa, Millett, Orchard, Penistaja, Potts, Progreso, Schelle, Stoneham, Tapia, Toluca, and Treasure series. Of these, only the Fattig, Hagerman, and Progreso soils have either paralithic or lithic contacts within depth of 40 inches. Fattig soils have dry value of 3 or 4 dry and 1 through 3 moist in the A and B horizons and formed in dark colored carbonaceous materials. Hagerman soils have 7.5YR or 5YR hue in the B2t horizon. Progreso soils have a lithic contact at depths of 21 to 40 inches.

Setting: The Cushman soils occur on upland bedrock plains. They formed in calcareous loam materials from weakly consolidated beds of mixed mineralogy. The climate is cool semiarid with mean annual temperature of 45° to 47°F., average summer temperature of 65°F. or warmer, and a mean winter temperature of 20° to 35°F. Mean annual precipitation is 10 to 14 inches, with 8 to 10 inches falling during April through October.

Principal Associated Soils: These are the Bainville, Briggsdale, McRae, Midway, Razor, and Tullock soils, and the competing Fort Collins soils. Bainville, Tullock, McRae, Midway, and Razor soils lack Bt horizons. Briggsdale soils have fine particle size class.

Drainage and Permeability: Well-drained; moderately permeable.

Use and Vegetation: Used for nonirrigated production of small grains and as rangeland. Native vegetation is western wheatgrass, prairie junegrass, needle-and-thread, blue grama, and sagebrush.

Distribution and Extent: Southeastern Montana and northern Wyoming. It is an extensive series.

Series Established: Big Horn County, Montana, 1941.

Remarks: The Cushman soils were formerly classified as Brown soils.

National Cooperative Soil Survey  
U. S. A.



Established Series  
Rev. SKB  
12/8/78

#### FARLAND SERIES

The Farland series consists of deep, well drained soils that formed in stratified alluvium on terraces and valley footslopes. Permeability is moderate or moderately slow. Slopes range from 0 to 9 percent. Mean annual precipitation is about 14 inches, and mean annual temperature is about 42° F.

Taxonomic Class: Fine-silty, mixed Typic Argiborolls.

Typical Pedon: Farland silt loam on an east facing 1 percent slope in native grassland. (Colors are for dry soil unless otherwise stated. When described, the soil was moist to 13 inches and dry below.)

A1--0 to 4 inches; dark grayish brown (10YR 4/2) silt loam, very dark brown (10YR 2/2) moist; weak medium and fine prismatic and fine subangular blocky structure parting to moderate fine granular; slightly hard, friable; many roots; many fine pores; neutral; gradual wavy boundary. (3 to 12 inches thick)

B2lt--4 to 11 inches; grayish brown (10YR 5/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine prismatic structure parting to strong medium and fine angular blocky; hard, friable; many roots; common fine pores; thin clay films on faces of peds; neutral; clear wavy boundary.

B22t--11 to 18 inches; grayish brown (2.5Y 5/2) silty clay loam, dark grayish brown (2.5Y 4/2) moist; moderate medium and fine prismatic structure parting to strong medium and fine subangular blocky; hard, friable; common roots; common fine pores; thin patchy clay films; neutral; gradual wavy boundary. (Combined thickness of B2 horizons 8 to 22 inches)

B3--18 to 25 inches; light yellowish brown (2.5Y 6/4) silt loam, grayish brown (2.5Y 5/2) moist; weak coarse prismatic and moderate coarse subangular blocky structure; hard, friable; few roots; common fine pores; strong effervescence; mildly alkaline; clear wavy boundary. (0 to 15 inches thick)

C1ca--25 to 34 inches; light yellowish brown (2.5Y 6/4) loam, light olive brown (2.5Y 5/4) moist; weak coarse prismatic and moderate coarse and medium subangular blocky structure; friable; few roots; few fine pores; violent effervescence with common coarse masses of soft lime; moderately alkaline; gradual boundary. (7 to 20 inches thick)

C2--34 to 60 inches; light brownish gray (2.5Y 6/2) stratified silt loam, loam and silty clay loam, olive brown (2.5Y 4/4) moist; weak coarse to fine subangular blocky structure parting to weak thin platy; friable; few roots; few fine pores; strong effervescence; moderately alkaline.

Type Location: Stark County, North Dakota; about 10 miles east of Richardton; 1,490 feet north and 1,200 feet west of SE corner, sec. 1, T. 139 N., R. 91 W.

Range in Characteristics: The solum thickness ranges from 12 to 36 inches and depth to free lime ranges from 8 to 30 inches. The profile is more than 40 inches thick to a paralithic contact or contrasting substratum. The mollic epipedon ranges from 8 to 16 inches in thickness.

The A horizon has 10YR hue, value of 4 or 5 and 2 or 3 moist, and chroma of 2 or 3. It is loam, silt loam or light clay loam.

The B2t horizon has 10YR or 2.5Y hue, value of 4 through 6 and 3 or 4 moist, and chroma of 2 to 4. It is silty clay loam, clay loam having a clay content which averages between 27 and 35 percent. Structure ranges from moderate to strong prismatic which parts to strong or moderate angular or subangular blocks. Peds in this horizon have thin continuous or patchy clay films.

The Cca horizon contains both diffuse and segregated soft masses of lime. The lower C horizon is typically loam, silt loam or silty clay loam alluvium, and less commonly stratified silt, silty clay, very fine sandy loam and very fine sand.

FARLAND SERIES--2

Competing Series: These are the Jekley, Morton and <sup>—</sup>Xavier series of the same family and the Agar, Arnegard, Belfield, Brussett, Farnuf, Grail, Savage, Sen, Shambo, Straw and Williams series. The Jekley and Morton soils have bedrock within depths of 40 inches. Jekley soils, in addition, occur at elevations above 7,700 feet. Xavier soils have thinner sola. Agar soils are mesic. Arnegard, Sen, Shambo and Straw soils lack argillic horizons. Arnegard and Straw soils, in addition, have mollic epipedons more than 16 inches thick. The Belfield soils have thin albic horizons, natric horizons, and are in the fine family. Brussett soils have lighter colored A horizons and thinner mollic epipedons. Farnuf and Shambo soils are fine-loamy. Grain soils have mollic epipedons more than 16 inches thick and are in the fine family. The Savage soils are in the fine family. Williams soils are formed in glacial till and are fine-loamy.

Geographic Setting: Farland soils are on nearly level to gently sloping terraces and footslopes of stream valleys. Slope gradients commonly average between 1 and 6 percent, but range from 0 to 9 percent. The soils formed in stratified alluvium of mixed mineralogy which contains little fine and coarser sand. The climate is cool, semiarid, with a mean annual temperature ranging from 38 to 45°F, and a mean annual precipitation from 12 to 16 inches. Most of the precipitation comes in the spring and summer.

Geographically Associated Soils: Belfield, Hanning, Marshall, Savage, Shambo, Stady and Straw soils are on adjacent terraces. Manning and Stady soils have gravelly IIC horizons at less than 40 inches. Straw soils are on low terraces subject to flooding. Soils on adjacent uplands are Morton, Regent, Sen and Vebar.

Drainage and Permeability: Well drained. Runoff is slow or medium. Permeability is moderate or moderately slow.

Use and Vegetation: Cultivated areas are used for growing small grains, flax, corn, hay and pasture. Some areas are irrigated for production of alfalfa, beans, corn, and sugar beets. Native vegetation is mid and short prairie grasses as green needlegrass, western wheatgrass and blue grama.

Distribution and Extent: Western North Dakota, eastern Montana and northwestern South Dakota. The series is of moderate extent.

Series Established: McKenzie County, North Dakota, 1932.

Remarks: The series was classified Chestnut in the former system.

Additional Data: S58ND-45-13, and S58ND-45-20 on pp. 88-91 of Soil Survey Investigation Report No. 2.

National Cooperative Soil Survey  
U.S.A.

Established Series  
Rev. AJC/RHM  
7/75

FORT COLLINS SERIES

The Fort Collins series consists of deep, well drained soils that formed mainly in alluvium. Fort Collins soils are on terraces and alluvial fans and have slopes of 0 to 10 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 47°F.

Taxonomic Class: Fine-loamy, mixed, mesic Ustollic Haplargids.

Typical Pedon: Fort Collins loam, grassland. (Colors are for dry soil unless otherwise noted.)

A1--0 to 5 inches; light brownish gray (10YR 6/2) loam, dark grayish brown (10YR 4/2) moist; moderate fine granular structure; soft, very friable; noncalcareous; neutral (pH 7.2); clear smooth boundary. (3 to 6 inches thick)

B1--5 to 8 inches; light brownish gray (10YR 6/2) loam, dark grayish brown (10YR 4/2) moist; moderate fine subangular blocky structure that parts to fine granular; hard, very friable; few glossy patches on faces of peds; noncalcareous; neutral (pH 7.2); clear smooth boundary. (3 to 4 inches thick)

B2t--8 to 18 inches; brown (10YR 5/3) heavy loam, dark brown (10YR 4/3) moist; moderate medium prismatic structure that parts to moderate fine subangular blocky; very hard, very friable; many thin wax-like patches and seams on faces of peds; thin wax-like coatings in root channels and pores; noncalcareous; mildly alkaline (pH 7.6); gradual smooth boundary. (5 to 12 inches thick)

B3ca--18 to 24 inches; pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; weak medium subangular blocky structure; hard, very friable; few thin glossy patches on faces of peds; weak glossy coatings in some root channels; some visible secondary calcium carbonate occurring mostly as concretions; calcareous; moderately alkaline (pH 8.0); gradual smooth boundary. (4 to 8 inches thick)

Cca--24 to 60 inches; pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; massive; hard, very friable; visible calcium carbonate occurring as concretions and in thin seams and streaks; calcareous; moderately alkaline (pH 8.2); gradual smooth boundary.

Type Location: Larimer County, Colorado; approximately 1 block north of LaPorte Avenue on North Shields Street, and 500 feet west of North Shields Street in sec. 11, T.7N., R.69W.

Range in Characteristics: Thickness of solum ranges from 15 to 30 inches. Depth to calcareous material ranges from about 8 to 20 inches. Organic carbon in the upper 15 inches ranges from .6 to 2 percent with a weighted average of approximately .8 percent. The average sand/clay ratio ranges from 1 to 3. The soil is 90 to 100 percent base saturated. Rock fragments range from 0 to 15 percent, but are typically less than 5 percent. Mean annual soil temperature ranges from 47° to 58°F., and mean summer soil temperature ranges from 59° to 78°F.

The A1 horizon has hue of 10YR or 2.5Y, value of 5 through 7 dry, 3 through 5 moist, and chroma of 2 or 3. When the value of the surface horizon is as dark as 5 dry and 3 moist the horizon must be thin enough so that if the soil is mixed to 7 inches it will have an ochric epipedon or it must contain less than 1 percent organic matter. This horizon is usually granular but the structure may be weak subangular blocky. It is soft or slightly hard and neutral to mildly alkaline.

The B2t horizon has hue of 2.5Y through 7.5YR, value of 5 through 7 dry, 4 or 5 moist, and chroma of 2 through 4. It is typically loam or light clay loam but clay ranges from 18 to 35 percent, silt from 20 to 50 percent, and sand from 20 to 50 percent with more than 15 percent but less than 35 percent being fine sand or coarser. This horizon is usually prismatic but is subangular blocky in some pedons. It is neutral or mildly alkaline (pH 7.0 to 7.8).

The C horizon has hue of 2.5Y or 10YR. It is moderate or strongly alkaline (pH 8.0 to 8.6) and has 5 to 14 percent calcium carbonate equivalent.

Competing Series: These are the Balon, Bowbac, Clovis, Cushman, Fattig, Gaddes, Hagerman, Harbord, Los Alamos, Maysdorf, Millett, Olney, Penistaja, Pokeman, Potts, Progresso, Pugsley, Scholle, Spenlo, Stoneham, Tapia and Toluca series. Balon soils are noncalcareous throughout, and lack continuous horizons of secondary carbonate accumulation. Clovis, Millett, Potts, and Scholle soils have lithochromic hue of 5YR or redder. Cushman, Pokeman and Pugsley soils have a paralithic contact at some point above depth of 40 inches. Fattig, Gaddes, Hagerman, and Progresso soils have a lithic contact at some point above depth of 40 inches. Los Alamos soils have pumice and ash within the control section and formed over thick pumice deposits. Stoneham and Toluca soils are less than 10 inches deep to the base of the B2t horizon or are less than 15 inches deep to the base of any B3ca horizon. Maysdorf, Olney, and Penistaja soils have more than 35 percent fine or coarser sand in the B2t and C horizons. Tapia soils have calcic horizons. Harbord soils have solums 30 to 50 inches thick, and have polygenetic solums in which a modern soil rests upon and merges with a paleosol.

Fort Collins Series

Geographic Setting: The Fort Collins soils are on terraces or alluvial fans. Gradients range from 0 to 10 percent. The soils formed in alluvium, which may in places have been modified by a thin mantle of eolian deposits. At the type location the average annual precipitation is 14 inches, with peak periods of precipitation occurring in the spring and early summer. Average annual temperature is 47°F., and average summer temperature is 66°F.

Geographically Associated Soils: These are the competing Stoneham and Olney soils.

Drainage and Permeability: Well-drained; medium runoff; moderate permeability.

Use and Vegetation: These soils are used as native pastureland and as dry and irrigated cropland. Principal crops under irrigation are small grains, alfalfa, corn, sorghums, and sugar beets. Dryland crops are limited primarily to winter wheat. Native vegetation is principally blue grama grass, wheatgrass and some buffalo grass.

Distribution and Extent: Eastern Colorado, Montana and Wyoming. The series is of moderately large extent.

Series Established: The Greeley Area, Colorado, 1904.

National Cooperative Soil Survey  
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GALATA SERIES

The Galata series is a member of the very-fine, montmorillonitic family of Borollic Glossic Natrargids. Typically, Galata soils have light gray, platy, light silty clay loam A2 horizons; light brownish gray, silty clay loam B&A horizons with many clear, unstained silt and fine sand on and throughout peds in A2 and B&A horizons; have yellowish brown grading to brown silty clay B2t horizons and light brownish gray clay C horizons with segregated lime in the Clca horizon. Gypsum and other salts occur in the lower part of, or below the Cca horizon.

Typifying Pedon: Galata silty clay loam - native grass  
(Colors are for dry soil unless otherwise noted.)

- A2 0-4"--Light gray (10YR 7/2) light silty clay loam, dark grayish brown (10YR 4/2) moist; moderate fine platy structure; vesicular; soft, friable, sticky, plastic; many very fine roots; neutral (pH 7.0); clear smooth boundary. (2 to 5 inches thick)
- B&A 4-8"--Light brownish gray (10YR 6/2) silty clay loam, dark grayish brown (10YR 4/2) moist; many clear silt and sand grains; moderate medium prismatic and strong fine platy structure; hard, friable, sticky, plastic; continuous clay film beneath clear silt frosting; common very fine roots; mildly alkaline (pH 7.5); clear smooth boundary. (3 to 6 inches thick)
- B2lt 8-14"--Yellowish brown (10YR 5/4) silty clay, dark grayish brown (10YR 4/2) moist; moderate medium prismatic structure that separates to strong blocky structure; extremely hard, very firm, very sticky, very plastic; moderately thick continuous clay films on peds; common very fine roots; moderately alkaline (pH 8.0); clear smooth boundary.
- B22t 14-21"--Brown (10YR 5/3) clay, dark brown (10YR 4/3) moist; moderate medium prisms that separate to strong coarse blocky structure; hard, very firm, very sticky, very plastic; thick continuous clay film on peds; black staining common on faces of peds; few very fine roots; moderately alkaline (pH 8.0); clear smooth boundary. (Bt horizon is 8 to 12 inches thick.)
- Clca 21-40"--Light brownish gray (10YR 6/2) clay, dark grayish brown (10YR 4/2) moist; strong coarse blocky structure; extremely hard, firm, sticky, plastic; few very fine roots; strong effervescence; many lime splotches; gradual smooth boundary. (10 to 30 inches thick)
- C2 40-60"--Light brownish gray (10YR 6/2) clay, dark grayish brown (10YR 4/2) moist; moderate medium and coarse blocky structure; extremely hard, firm, sticky, plastic; strong effervescence; common lime splotches.

Type Location: Powder River County, Montana; N1/4 of NW1/4 of sec. 15, T.7S., R.47E.

Range in Characteristics: Galata soils have mean annual soil temperature of 44° to 47°F. and are dry between depths of 4 and 12 inches for more than 1/2 the time when not frozen. The A2 horizon has value of 6 or 7 dry. The Ap horizon has value greater than 5 dry and greater than 3.5 moist with chroma of 2 or 3. A very thin Al horizon may be present in some pedons. The combined thickness of the A2 and the B&A horizons is 6 to 9 inches. Under cultivation, all of the A2 horizon and nearly all of the B&A horizons are incorporated into the Ap horizon giving the plowed soil a distinct grayish cast with many clear mineral grains. The Ap horizon is soft and granular. The B2t horizon has hue of 10YR or 2.5Y, value of 4 or 5 dry, and chroma of 3 or 4. It has an estimated 60 to 75 percent clay with an absolute difference over the Ap horizon of 25 to 35 percent clay and 8 to 15 percent more clay than in the C horizon. The estimated sodium saturation ranges from 5 to 10 percent in the upper B horizon and 10 to 20 percent in the lower B horizon with exchangeable Ca:Mg ratio of 1 or less. The lower part of the B2t horizon is weakly calcareous in some pedons. The B3ca horizon has few to common nodules of lime and the Cca horizon has common to many nodules of lime and has 45 to 60 percent clay. The B3ca and Cca horizons have estimated 15 to 25 percent exchangeable Na. The lower part of the pedon is stratified with coarser textured materials in some pedons.

Competing Series and their Differentiae: These are the Allentine, Arvada, Gilt Edge, Hydro, and Rapelje series. Allentine and Gilt Edge soils have columnar B2t horizons and the Allentine soils have the upper boundary of the B2t horizon at depths of less than 5 inches below the surface. Arvada soils have strongly alkaline, columnar, fine textured B2t horizons with more than 15 percent exchangeable Na in the major part and with its upper boundary within five inches below the surface and have a mean annual temperature warmer than 47°F. Hydro soils have silty clay B2t horizons and have soil temperature warmer than 47°F. Rapelje soils have silt loam or silty clay loam B2t horizons.

Galata Series

Setting: Galata soils are on plains of the uplands <sup>and</sup> on terraces in valleys. The parent materials are of deep calcareous clays in which the clay type is dominantly montmorillonitic. The climate is cool semiarid with mean annual temperature of 40° to 45°F., mean summer temperature more than 66°F. and mean winter temperature of 18° to 26°F. Mean annual precipitation is 11 to 14 inches.

Principal Associated Soils: These are the competing Gilt Edge soils and the Landusky, Marias, and Phillips soils. Landusky soils have a mollic epipedon and lack a natric horizon. Marias soils lack diagnostic subsurface horizons. Phillips soils have less clay and lack natric horizons. Galata soils occur in small and large areas in complex association with these soils.

Drainage and Permeability: Well-drained; slow permeability.

Use and Vegetation: Used mainly for nonirrigated production of small grains. Native vegetation is western wheatgrass, Sandberg bluegrass, prairie junegrass, needle-and-thread, blue grama, and scattered Gardner saltbush.

Distribution and Extent: Northern and eastern plains of Montana. Galata series is moderately extensive.

Series Established: Powder River County Montana, 1972.

Remarks: The Galata soils were formerly classified as solodized-Solonetz soils.

National Cooperative Soil Survey  
U. S. A.

Established Series  
Rev. AJC/JEB  
7/78

### HAVERSON SERIES

The Haverson series consists of deep, well drained soils that formed in alluvium from mixed sources. Haverson soils are on floodplains and low terraces and have slopes of 0 to 6 percent. The mean annual precipitation is about 16 inches and the mean annual temperature is about 52° F.

Taxonomic Class: Fine-loamy, mixed (calcareous), mesic Ustic Torrifuvents.

Typical Pedon: Haverson loam - grassland. (Colors are for dry soil unless otherwise noted.)

A1--0 to 6 inches; light brownish gray (10YR 6/2) loam, dark grayish brown (10YR 4/2) moist; moderate very fine granular structure; soft, very friable; calcareous; moderately alkaline (pH 8.2); clear smooth boundary. (4 to 8 inches thick)

C--6 to 60 inches; light brownish gray (10YR 6/2) loam stratified with thin lenses of clay loam and fine sandy loam, dark grayish brown (10YR 4/2) moist; weighted average texture approximately a loam; massive; slightly hard, very friable; a very small amount of secondary calcium carbonate as soft concretions; calcareous; moderately alkaline (pH 8.2).

Type Location: Prowers County, Colorado; approximately .8 mile south and .1 mile east of NW corner sec. 29, T. 22 S. R. 45 W.

Range in Characteristics: Organic carbon ranges from .6 to 1.5 percent in the surface horizon but decreases irregularly with depth. The control section is stratified with strata ranging from sandy loam to clay loam, but averaging approximately loam. On a weighted average basis clay ranges from 18 to 35 percent, silt from 10 to 50 percent, and sandy from 20 to 60 percent with more than 15 percent but less than 35 percent being fine or coarser sand. Rock fragments are generally less than 5 percent and range from 0 to 15 percent. Some visible calcium carbonate may occur at any depth in these soils, but it is not concentrated into any consistent horizon of accumulation. Mean annual soil temperature ranges from 47 to 58° F. and mean summer soil temperature ranges from 59 to 78° F.

The A horizon has hue of 2.5Y or 10YR, value of 5 or 6 dry, 3 through 5 moist and chroma of 2 or 3. When the value of the surface horizon is as dark as 5 dry and 3 moist, the horizon is thin enough so that if mixed to 7 inches it is too light colored or contains too little organic carbon to qualify as a mollic epipedon. The A horizon usually has granular primary structure but it has subangular blocky structure in some pedons. It is soft or slightly hard. It is neutral through or moderately alkaline.

The C horizon has hue of 2.5Y through 7.5YR. It is mildly alkaline to strongly alkaline. It has from less than 1 to about 3 percent calcium carbonate equivalent which differs erratically from stratum to stratum.

Competing Series: These are the Barnum, Havre, Hysham and San Mateo series. Barnum soils have lithochromic hue of 5YR or redder and Havre soils have frigid soil temperature. Hysham soils are very strongly alkaline and have a very hard or extremely hard B2 horizon. San Mateo soils have chroma of 3 or 4 in the control section.

Geographic Setting: The Haverson soils are on floodplains and low terraces of major rivers. Slope is 0 to 6 percent. The soils formed in highly stratified, calcareous, recent alluvium derived from mixed sources. At the type location the average annual precipitation is 16 inches with peak periods of precipitation occurring during the early spring and summer. The average annual temperature is 52° F. and the average summer temperature is 77° F. The frost-free season is 125 to 180 days.

Geographically Associated Soils: These are the Bankard and Glenberg soils. Bankard and Glenberg soils have less than 18 percent clay in the series control section.

Drainage and Permeability: Well drained; slow runoff; moderate permeability.

Use and Vegetation: These soils are used as native pastureland, dry farm land or irrigated cropland. Native vegetation is mixed grasses, cottonwoods and brush.

Distribution and Extent: Eastern Colorado and Wyoming, northeastern New Mexico and adjacent states. The soil is of large extent.

Series Established: Red Willow County, Nebraska, 1965.

Remarks: Differentiation from San Mateo series needs further study.



### HELDT SERIES

The Heldt series is a member of the fine, montmorillonitic, mesic family of Ustertic Camborthids. Typically, Heldt soils have friable granular calcareous A horizons, B2 horizons having moderate prismatic and angular blocky structure, and fine textured calcareous C horizons that have consistent accumulation of secondary calcium carbonate.

Typifying Pedon: Heldt silty clay loam - grassland  
(Colors are for dry soil unless otherwise noted.)

- A1 0-6"--Light brownish gray (2.5Y 6/2) heavy silty clay loam, grayish brown (2.5Y 5/2) moist; strong very fine granular structure; soft, very friable; plastic, sticky, calcareous; moderately alkaline (pH 8.2); clear smooth boundary. (5 to 10 inches thick)
- B2 Light brownish gray (2.5Y 6/2) silty clay, grayish brown (2.5Y 5/2) moist; moderate coarse prismatic structure that parts to moderate coarse angular blocks; extremely hard, friable, very sticky, very plastic; few glossy patches on faces of peds and in root channels; common shiny slickensides; calcareous; strongly alkaline (pH 8.5); gradual wavy boundary. (15 to 40 inches thick)
- Clca 40-60"--Light gray (2.5Y 7/2) silty clay, grayish brown (2.5Y 5/2) moist; few fine faint reddish brown (5YR 5/4) mottles; massive; extremely hard, firm, very sticky, very plastic; some visible calcium carbonate occurring as concretions and in thin seams and streaks; few calcium sulfate crystals; calcareous; moderately alkaline (pH 8.3); gradual smooth boundary. (6 to 12 inches thick)

Type Location: Goshen County, Wyoming; 517 feet east and 187 feet north of the east abutment of the bridge over Cherry Creek on the road to Veteran, in the SW1/4 SE1/4 SW1/4 sec. 25, T.24N., R.62W.

Range in Characteristics: Average organic content of the A1 horizon is .6 to 2 percent, and decreases uniformly with depth to less than .2 percent at depth of 50 inches. Sand/clay ratio is 1 or less. Conductivity typically ranges from less than 1 to about 2 millimhos in the control section. Cation exchange capacity is 70 to 100 milliequivalents per 100 grams of clay. The soils are usually calcareous throughout but depth to calcareous material ranges from 0 to 15 inches. Exchangeable sodium percentage usually ranges from less than 1 to 5 percent in the upper part of the control section but may increase with depth. The 10- to 40-inch section is usually clay or silty clay but ranges in clay from 35 to 50 percent, in silt from 10 to 50 percent, and in sand from 10 to 45 percent. Content of coarse fragments is typically less than 5 percent but ranges from 0 to 15 percent. The solum is 20 to 50 inches thick. C.O.L.E. values are .04 to .095 and usually exceed .05 in some horizon as thick as 20 inches; and total extensibility of the soil above 40 inches is greater than 2.4 inches. Cracks more than .4 inch wide, and 12 inches long occur in the upper 20 inches when the soils is dry and the cracks remain open for 90 to 270 (cumulative) days in most years. Mean annual soil temperature is 47° to 58° F., and mean summer soil temperature is 59° to 78° F. The soil temperature at depth of 20 inches is 41° F. or higher for about 230 to 305 days. The soil is moist in some part of the control section for 56 to 152 days while the soil temperature is above 41° F. The A1 horizon has hue of 5Y through 7.5YR, value of 5 through 7 dry and 3 through 6 moist, and chroma of 1 through 4. Surface horizons having value as dark as 5 dry and 3 moist should be too thin or contain too little organic matter to be mollic epipedons. The horizon is usually granular but is subangular blocky in some pedons. It is soft to slightly hard. It is moderately to strongly alkaline (pH 8.0 to 8.6). The B2 horizon has hue of 5Y through 7.5YR, value of 5 through 7 dry and 4 through 6 moist, and chroma of 2 through 5. It is usually prismatic but is angular blocky in some pedons. It is moderately to strongly alkaline (pH 8.0 to 8.5). The C horizon has hue of 5Y through 7.5YR. It is moderately to strongly alkaline (pH 8.0 to 8.5) and has 3 to 10 percent calcium carbonate equivalent.

Competing Series and their Differentiae: These are the Diaz and Dominguez series. Diaz soils have bedrock above 40 inches. Dominguez soils have hue of 5YR or redder.

## Heldt Series

Setting: The Heldt soils are on gently sloping alluvial fans or valley side slopes. Gradients range from 1 to 6 percent. The soils formed in fine textured alluvial fan sediments derived primarily from sedimentary rock. At the type location the average annual precipitation is 15 inches with peak periods of precipitation occurring in the spring and early summer months. Average annual temperature is 48° F., and average summer temperature is 69° F.

Principal Associated Soils: These are the Orella and Samsil soils. Orella and Samsil soils have bedrock at depths of less than 20 inches.

Drainage and Permeability: Well to moderately well drained; slow or very slow runoff; slow to permeability.

Use and Vegetation: These soils are used principally as native pastureland, although they may be tilled to both dryland and irrigated crops in some localities. Native vegetation is primarily western wheat, blue grama, cactus, and some poverty grass.

Distribution and Extent: Eastern Colorado, Montana, and Wyoming. The series is of moderate extent.

Series Established: Big Horn County (Big Horn Area), Montana, 1970.

National Cooperative Soil Survey  
U. S. A.

Established Series  
Rev. RLM-CAM  
4-68

# HESPER SERIES

The Hesper series is a member of the fine, montmorillonitic, mesic family of Ustollic Haplargids. Typically, these soils have grayish brown silt loam A1 horizons less than 5 inches thick, brown heavy silty clay loam B2t horizons that have strong fine prismatic and blocky structure, and C horizons of olive silt loam that has distinct accumulation of calcium carbonate.

Typifying Pedon: Hesper silty clay loam - native grass  
(Colors are for dry soil unless otherwise noted.)

- A1 -- 0-2" -- Grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak thin platy structure parting to weak very fine crumb structure; soft, very friable, slightly sticky; common bleached silt and very fine sand-size particles; moderately acid (pH 5.8); abrupt boundary. (2 to 5 inches thick.)
- B2t -- 2-11" -- Brown (10YR 4/3) to (10YR 5/3) crushed heavy silty clay loam, dark brown (10YR 3/3) moist, brown (10YR 4/3) crushed moist; strong fine and medium prismatic structure separating easily to strong fine and very fine subangular blocky structure; very hard, friable, sticky, plastic; moderately thick continuous clay films coating and bridging mineral grains and partly filling many pores; neutral (pH 7.0); clear boundary. (8 to 12 inches thick.)
- B3 -- 11-16" -- Dark grayish brown (10YR 4/2), light olive brown (2.5Y 5/3) crushed, silty clay loam, very dark grayish brown (10YR 3/2) moist, olive brown (2.5Y 4/3) crushed moist, strong medium prismatic structure separating to strong fine, subangular blocky structure; hard, friable, sticky, plastic; moderately thick and continuous clay films coating and bridging mineral grains; mildly alkaline (pH 7.7); gradual wavy boundary. (2 to 5 inches thick.)
- C1ca-- 16-20" -- Light olive brown (2.5Y 5/3) light silty clay loam, olive brown (2.5Y 4/3) moist; moderate medium and fine blocky structure; hard, friable, sticky, slightly plastic; moderate effervescence; common white nodules of lime; moderately alkaline (pH 8.3); gradual boundary.
- C2ca-- 20-44" -- Pale olive (5Y 6/3) heavy silt loam, olive gray (5Y 4/2) moist; blocky structure; hard, very friable, slightly sticky, slightly plastic; moderate effervescence; many soft white nodules of lime; moderately alkaline (pH 8.3); gradual boundary.
- C3 -- 44-60" -- Olive (5Y 5/3) very fine sandy loam, olive (5Y 4/3) moist; blocky structure; soft, very friable, slightly sticky; moderate effervescence, few seams of lime; moderately alkaline (pH 8.3).

Type Location: Yellowstone County, Montana; just east of road near fence corner in northwestern part of SE 1/4 sec. 33, T. 2 N., R. 29 E.

Range in Characteristics: Hesper soils are usually dry between depths of 4 and 12 inches when soil temperature is warmer than 41° F., but they are not dry in all parts above 12 inches for more than half the time during this period. Mean annual soil temperature ranges from 47° to 50° F.

Thickness of solum ranges from 10 to 20 inches. Most pedons have Ap horizons 5 to 8 inches thick of silty clay loam. The color hue ranges from 2.5Y through 7.5YR throughout the soil. The A1 horizon has value of more than 5 dry and more than 3 moist and chroma of 2 or 3. These values are one-half to one unit more than those of coatings in the upper part of the B2 horizon. Clear uncoated silt and fine sand grains are abundant in the A horizon. The B horizon has chroma of 2 through 4. The finest texture is in the upper 3 to 5 inches of the B2t horizon, starting at depths of 2 to 5 inches below the surface. These layers contain between 35 and 50 percent clay. In plowed soils they are mixed in the Ap horizon. The B2t horizon remaining beneath the Ap horizon ranges from 35 to 45 percent clay and contains 2 to 8 percent more clay than the Ap horizon. Distinct clay films are on faces of peds in the B2 horizon, and many pores are partially filled with clay. The Cca horizon contains less than 15 percent CaCO<sub>3</sub> equivalent but has accumulations of secondary lime. The C horizon is silt loam that contains less than 15 percent fine and coarser sand. Some pedons have IIC horizons of contrasting texture below depths of 40 inches.

Competing Series and their Differentiae: Similar and related soils are in the Baca, Bew, Big Horn, Fort Collins, Hinman, Renohill, Thurlow, and Ulm series. The Baca soils have A and B1 horizons 5 to 10 inches thick above the B2t horizon and a more gradual increase in amount of clay from the A to the B horizon. The Bew soils have 50 to 60 percent clay in their argillic horizon. The Big Horn soils have more than 10 percent more clay in the upper part of the B2t horizon than in the Ap horizon. The Fort Collins soils have less than 35 percent clay and more than 15 percent fine and coarser sand in the B2t horizon. The Hinman soils have calcareous soils. The Renohill soils have soft rock at depths between 20 and 40 inches. The Thurlow and Ulm soils have more than 15 percent fine and coarser sand in their argillic horizons and C horizons; and the Ulm soils, in addition, have 5 to 10 inches of A and B1 horizon above the B2t horizon.

**Hesper Series**

Setting: Hesper soils are on upland plains and on terraces. They formed in uniform calcareous silt loam. The climate is cool semiarid. Mean annual temperature ranges from 45° to 48° F., mean summer temperature from 64° to 67° F., and mean winter temperature from 0 to 28° F. Mean annual precipitation ranges from 10 to 14 inches and about 8 inches falls from April through August.

Principal Associated Soils: These are the competing Fort Collins and Thurlow soils, and the Keiser and Wanetta soils. Keiser soils have sola less than 10 inches thick. The Wanetta soils have IIC horizons of loose sand and gravel at depths of 20 to 40 inches.

Drainage and Permeability: Well drained. The B horizon is moderately permeable.

Use and Vegetation: Used primarily for cropland, both irrigated and nonirrigated. A few areas are still in native vegetation of western wheatgrass, needle-and-thread, blue grama, prairie Junegrass, and big sagebrush.

Distribution and Extent: Southeastern Montana. The soil is extensive.

Series Established: Treasure County, Montana, 1963.

Remarks: Hesper series was formerly classified in the Brown great soil group.

Established Series  
Rev. TJH  
12/72

## HOPLEY SERIES

The Hopley series is a member of the coarse-loamy, mixed family of Typic Haploborolls. Typically, Hopley soils have loam profiles with granular, dark grayish brown Ap horizons, grayish brown B<sub>2</sub> and B<sub>3</sub> horizons, and light brownish gray Cca horizons over IIC horizons of soft calcareous sandstone at a depth of 42 inches.

Typifying Pedon: Hopley loam - cultivated  
(Colors are of dry soil unless otherwise stated.)

- Ap 0-7"--Dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; moderate medium granular structure; slightly hard, friable, nonsticky, nonplastic; neutral; clear smooth boundary. (Al horizon is 5 to 7 inches thick.)
- B<sub>2</sub> 7-10"--Grayish brown (10YR 5/2) heavy loam, very dark grayish brown (10YR 3/2) moist; moderate medium prismatic structure; hard, friable, slightly sticky, slightly plastic; patches of thin clay film on faces of peds; neutral; clear boundary. (3 to 5 inches thick)
- B<sub>3</sub> 10-14"--Grayish brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) moist; weak coarse prismatic structure; hard, friable, nonsticky, slightly plastic; slightly effervescent; moderately alkaline (pH 8.2); gradual boundary. (4 to 6 inches thick)
- Cca 14-42"--Light brownish gray (2.5Y 6/2) light loam, grayish brown (2.5Y 5/2) moist; massive; slightly hard, friable, nonsticky, slightly plastic; strongly effervescent, common filaments of lime; moderately alkaline (pH 8.2); clear boundary. (28 to 42 inches thick)
- IIC<sub>2</sub> 42-54"--Soft, calcareous sandstone.

Type Location: Yellowstone County, Montana; 100 feet south and 20 feet east of NW corner of sec. 2, T.2S., R.24E.

Range in Characteristics: Volume of rock fragments in the 10 to 40 inch section ranges from 0 to 20 percent. The mollic epipedon is 7 to 10 inches thick. The noncalcareous part of the solum is 12 to 18 inches thick. Hue is 10YR or 2.5Y throughout the soil. The Al horizon is loam or fine sandy loam with value of 3 or 4 dry, 2 or 3 moist, and chroma of 2 or 3. The B<sub>2</sub>, B<sub>3</sub>, and Cca horizons are loam containing 10 to 18 percent clay and 15 to 35 percent coarser than very fine sand. IIC horizons of soft sandstone, silty shale or gravelly sand occur below depths of 40 inches in some pedons.

Competing Series and their Differentiae: These are the Bitterroot, Panguitch, Relan, Talley, Vebar, and Victor series. Bitterroot and Vebar soils have soft bedrock at depths of 20 to 40 inches. Talley soils have more than 35 percent coarser than very fine sand in their control sections. Panguitch soils are noncalcareous to depths of more than 18 inches and formed in alluvium of volcanic origin. Relan soils have hue of 7.5YR or redder. Victor soils have gravelly sand layers at depths of 20 to 30 inches.

Setting: Hopley soils are on nearly level to steep uplands and old terraces at elevations of 2,500 to 4,000 feet. The soils formed in calcareous loamy alluvium. Average annual precipitation is 12 to 16 inches. Mean annual temperature is 38° to 45°F. Mean January temperature is 8° to 25°F. Mean July temperature is 60° to 70°F. The frost-free period is 100 to 135 days.

Principal Associated Soils: These are the Castner, Lambert, and Farland soils. Castner soils have bedrock at depths of 10 to 20 inches. Lambert and Farland soils have fine-silty control sections.

Drainage and Permeability: Well-drained; slow to medium runoff; moderate permeability.

Use and Vegetation: Hopley soils are used for dry farmed cropland and for rangeland. Wheat, barley, and oats are the main crops. Native vegetation is western wheatgrass, needle-and-thread, blue grama, prairie junegrass, and threadleaf sedge.

Distribution and Extent: Eastern and central Montana. The series is moderately extensive.

Series Established: Yellowstone County, Montana, 1972.

Remarks: Hopley soils were formerly classified as Chestnut soils.



Series Established  
Rev. CAM-JLP  
2/72

#### RELAN SERIES

The Relan Series is a member of the coarse-loamy, mixed, family of Typic Haploborolls. Typically, Relan soils have brown grading to dark brown gravelly loam A1 horizons and pinkish gray, calcareous, gravelly loam C horizons with segregations of lime in the upper part.

Typifying Pedon: Relan gravelly loam - native grass cover  
(Colors are for dry soil unless otherwise noted.)

- A11 0-8"--Brown (7.5YR 5/2) gravelly loam, dark brown (7.5YR 3/2) moist; weak fine blocks that separate to weak fine crumb structure; soft, friable, nonsticky, nonplastic; many very fine roots and fine interstitial pores; common fine "scoria" fragments that give dark reddish brown color to rubbed moist soils; neutral (pH 7.4); gradual boundary.
- A12 8-13"--Dark brown (7.5YR 4/2) gravelly loam, dark brown (7.5YR 3/3) moist; weak fine crumb structure; soft, friable, nonsticky, nonplastic; many very fine roots and fine interstitial pores; common fine "scoria" fragments that give dark reddish brown color to rubbed moist soil; noncalcareous; mildly alkaline (pH 7.6); clear wavy boundary. (A1 horizon is 8 to 18 inches thick)
- C1ca 13-26"--Pinkish gray (7.5YR 6/4) gravelly light loam, brown (7.5YR 5/4) moist; massive; slightly hard, friable, nonsticky, nonplastic; common very fine roots and fine tubular pores; common fine "scoria" fragments; strongly calcareous with fine segregations of lime; moderately alkaline (pH 8.4); gradual boundary. (10 to 20 inches thick)
- C2 26-30"--Pinkish gray (7.5YR 6/4) gravelly fine sandy loam, dark brown (7.5YR 4/4) moist; massive; soft, very friable, nonsticky, nonplastic; common very fine roots and fine tubular pores; numerous fine "scoria" fragments; strongly calcareous; strongly alkaline (pH 8.6); gradual boundary.
- C3 30-62"--Pinkish gray (7.5YR 6/4) gravelly light loam that consists of stratified sand, silt, loam and small gravel in place; dark brown (7.5YR 4/4) moist; soft, very friable, nonsticky, nonplastic; few very fine roots and common fine tubular pores; strongly calcareous; strongly alkaline (pH 8.6).

Type Location: Powder River County, Montana; 1,200 feet north and 800 feet west of SE corner sec. 12, T.4S., R.50E.

Range in Characteristics: Mean annual soil temperature is 44° to 47° F. and the average summer temperature is 60° to 64° F. Texture below the A1 or Ap horizon averages loam or sandy loam with 7 to 18 percent clay, more than 15 percent fine and coarser sand and 15 to 30 percent fine gravel of porcelanite fragments. The hue is 7.5YR and redder with chroma of 2 through 4. The Ap and A1 horizons have value of 4 or 5 dry. The Cca horizon is weak with few to many segregations of thread and film lime and a CaCO<sub>3</sub> content of 8 to 12 percent. Loose porcelanite beds occur at depths greater than 40 inches.

Competing Series and their Differentiae: These are the Bass, Bitterroot, Groveland, Hopley, Kalispell, Manning, Panguitch, Tally, Twin Creek, Vebar, and Victor series. Bass, Groveland and Kalispell soils have udic summer moisture regime and have moist value of 2 in the A1 horizons. Bass, Manning and Victor soils have very gravelly sandy substrata below depth of about 30 inches. Also, Bass soils have considerable mica from included granitic rock fragments. Bitterroot and Vebar soils have paralithic contacts with sandstone at depths of 20 to 40 inches. Hopley soils have hue yellower than 7.5YR. Panguitch soils have cambic horizons and are deeper than 18 inches to the Cca horizons. Tally and Vebar soils have fine sandy loam pedons. Twin Creek soils have 18 to 27 percent clay in the 10- to 40-inch section.

Setting: The Relan soils are on terraces and alluvial fans and on floors of swales in the uplands. The parent material is of mixed mineral origin, consisting of local transported materials from red porcelanite beds and soils developed over these beds. The climate is cool semiarid with mean annual temperature colder than 45° F. and mean summer temperature warmer than 65° F. Mean annual precipitation is 15 to 19 inches with 9 to 12 inches falling during May to September.

Principal Associated Soils: These are the Dillinger, Fergus, Ringling, and Searing soils, and the competing Twin Creek soils. Dillinger soils have loamy control sections. Fergus soils have an argillic horizon. Ringling soils have red porcelanite beds at depths shallower than 20 inches. Searing soils have porcelanite beds at depths of 20 to 40 inches.

Relan Series

Drainage and Permeability: Well-drained; moderate permeability.

Use and Vegetation: Used for native grass range and for dryland crop production. Native vegetation is mid grasses and sagebrush--needle-and-thread, green needlegrass, blue grama and western wheatgrass.

Distribution and Extent: Relan soils occur throughout eastern Montana where they are inextensive.

Series Established: Powder River County (Powder River Area), Montana, 1972.

Remarks: The Relan soils were formerly classified as Chestnut soils.

National Cooperative Soil Survey  
U. S. A.

Established Series  
Rev. CAM  
11/70

HYDRO SERIES

The Hydro series is a member of the fine, montmorillonitic, mesic family of Glossic Ustollic Natrargids. Typically, Hydro soils have thin platy loam A2 horizons, mixed A&B transition horizons, prismatic and blocky clay B2t horizons, and Cca horizons in deep unconsolidated loam or clay loam materials.

Typifying Pedon: Hydro loam - grassland  
(Colors are for dry soil unless otherwise noted.)

- A1 0-1"--Dark grayish brown (2.5Y 4/2) loam, very dark grayish brown (2.5Y 3/2) moist; moderate thin platy structure that separates to moderate very fine granules; slightly hard, very friable, slightly sticky, slightly plastic; many very fine roots and tubular pores; slightly acid (pH 6.2); clear boundary. (1 to 3 inches thick)
- A2 1-4"--Light gray (2.5Y 7/2) on top of plates and light brownish gray (2.5Y 6/2) on bottom of plates, loam, grayish brown and dark grayish brown (2.5Y 5/2 and 4/2) crushing to dark grayish brown (2.5Y 4/2) moist; very thin platy structure; slightly hard, very friable, slightly sticky, slightly plastic; many very fine roots and tubular pores; surfaces of plates have a continuous coating of uncoated mineral grains on top and undersides; slightly acid (pH 6.2); clear boundary. (2 to 4 inches thick)
- A&B 4-11"--Light gray (2.5Y 7/2) on top of plates and light brownish gray (2.5Y 6/2) on underside of plates, light clay loam, dark grayish brown (2.5Y 4/2) moist; moderate coarse prismatic structure that separates to strong very thin plates in upper part and strong very fine blocks in lower part; slightly hard, very friable, slightly sticky, slightly plastic; many very fine roots and tubular pores; plates have continuous thick frosting of uncoated mineral grains on top and undersides, blocks have thin coating of uncoated silt grains; slightly acid (pH 6.3); clear boundary. (4 to 8 inches thick)
- B2t 11-21"--Pale brown (10YR 6/3) light clay, light olive brown (2.5Y 5/3) moist; dark brown (10YR 4/3) coating on peds; moderate medium prismatic structure that separates to strong fine and very fine blocks; extremely hard, firm, sticky, plastic; common very fine roots, mainly between prisms; thin continuous clay films; few stained sand grains; moderately alkaline (pH 8.0); clear boundary. (6 to 10 inches thick)
- B3ca 21-31"--Light olive brown (2.5Y 5/3) heavy clay loam, olive brown (2.5Y 4/3) moist; weak medium and coarse prismatic structure that separates to moderate medium blocks; very hard, friable, sticky, plastic; few roots; thin patchy clay films; moderate effervescence with common lime nodules; strongly alkaline (pH 8.4); clear boundary. (5 to 15 inches thick)
- Clca 31-36"--Light olive brown (2.5Y 5/3) heavy clay loam, olive brown (2.5Y 4/3) moist; weak coarse blocky structure; very hard, friable, sticky, plastic; few roots; moderate effervescence with common soft lime nodules and few nests and seams of gypsum in lower part; strongly alkaline (pH 8.4).
- C2cs 36-51"--Light olive brown (2.5Y 5/3) clay loam, olive brown (2.5Y 4/3) moist; weak coarse blocky structure; hard, friable, sticky, plastic; very few roots; moderate effervescence with few soft lime segregations and with common segregations of gypsum in seams and nests of crystals; moderately alkaline (pH 8.2); gradual boundary. (0 to 20 inches thick)
- C3 51-60"--Light olive brown (2.5Y 5/3) clay loam, olive brown (2.5Y 4/3) moist; weak coarse blocky structure; hard, friable, sticky, plastic; moderate effervescence; moderately alkaline (pH 8.2).

Type Location: Powder River County, Montana; 1,200 feet east and 1,200 feet north of S1/4 corner of section 11; T9S, R53E.

## Hydro Series

Range in Characteristics: Hydro soils are usually dry between depths of 4 and 12 inches when soil temperature at 20 inches is warmer than 41 degrees F., but they are not dry in all parts above 12 inches for more than half the time during this period. The mean annual soil temperature ranges from 48 to 50 degrees F. Hues are 2.5Y through 7.5YR throughout the soil profile. or the Bt horizon may be one hue redder than the C horizons. The combined thickness of A1, A2 and A&B horizons is 5 to 10 inches and of the noncalcareous part of solum 12 to 18 inches. The Ap horizon has value greater than 5 dry and 4 or more moist. The A2 horizon has value of 6 or 7. The A&B transition horizon is heavy loam or clay loam. Prisms of this horizon separate to fine blocks in some pedons. The coating on the plates and prisms shows many clear uncoated grains with chroma of 1 or 2 and value of 5 or greater. The broken and crushed surfaces have one unit stronger chroma. The B2t horizon has value of 5 or less dry and chroma of 2 or 3 both coated and crushed. It has 38 to 45 percent clay. It has fragile columns in some pedons but these separate easily to fine blocks. In some pedons the blocky structure continues to depths of 28 to 30 inches. Percent sodium saturation ranges from 5 to 10 percent in the B horizon and extractable Ca/Mg ratio is less than 1 in some part of the horizon. The C horizon has more than 15 percent exchangeable sodium in some part within a depth of 60 inches. It has a ratio of extractable Ca to Mg of less than 1 in the upper part. Where gypsum or other more soluble salts are present, these are usually below 30 inches

Competing Series and their Differentiae: These are the Allentine, Arvada, Bone, Galata, Gilt Edge and Winnett series. These soils have an abrupt boundary between the A and the B horizons and have less than one inch of tonguing of the A into the top of the Bt horizon. Arvada and Bone soils have more than 15 percent exchangeable sodium in the B horizon. Gilt Edge and Winnett soils have strong columnar Bt horizons beneath ochric epipedons 5 or more inches thick. Galata soils have more than 60 percent clay in the argillic horizon and have mean annual soil temperature colder than 47 degrees F.

Setting: The Hydro soils are on nearly level to sloping terraces and foot slopes. They formed in very deep transported calcareous loam or clay loam materials of mixed rock origin. The climate is cool semiarid with mean annual air temperature ranging from 45 to 48 degrees F., mean summer air temperature of 65 to 70 degrees F., a frost-free period of 95 to 150 days, and a mean annual precipitation of 10 to 15 inches with 8 to 10 inches of warm season rainfall.

Principal Associated Soils: These are the Fort Collins, Thurlow and Cushman soils and the competing Arvada soils. These soils lack A2 horizons, have prismatic or blocky structured B2t horizons with neutral or moderately alkaline reaction, and have less than 7 percent exchangeable sodium in any part of the B2t horizon with a wide Ca/Mg exchange ratio of more than 1.5.

Drainage and Permeability: Well-drained; slow permeability.

Use and Vegetation: Used for irrigated and nonirrigated cropland and for rangeland. Large areas still have western wheatgrass, prairie junegrass, blue grama, and silver sagebrush.

Distribution and Extent: An extensive soil occurring in small areas widely distributed throughout the eastern and northern plains of Montana.

Series Established: Big Horn County (Big Horn Area), Montana, 1970.

Remarks: The Hydro soils were formerly classified as Solodized-Solonetz soils.

Established Series  
Rev. DLB-RER-LDZ  
12/7/79

### KYLE SERIES

The Kyle series consists of deep, well drained soils formed in sediments weathered from clay shale on uplands. Permeability is very slow. Slopes range from 0 to 9 percent. Mean annual precipitation is about 16 inches, and mean annual temperature is about 46° F.

Taxonomic Class: Very-fine, montmorillonitic, mesic Ustertic Camborthids.

Typical Pedon: Kyle clay - on a west-facing plane slope of 2 percent in native grass. When described the soil was moist to 50 inches. (Colors are for dry soil unless otherwise stated.)

A1--0 to 4 inches; grayish brown (2.5Y 5/2) clay, dark grayish brown (2.5Y 4/2) moist; moderate medium and fine granular structure; hard, firm, sticky and plastic; thin crust in upper 1/4 inch of light brownish gray (2.5Y 6/2); common fine roots; neutral; clear wavy boundary. (2 to 6 inches thick)

B21--4 to 8 inches; grayish brown (2.5Y 5/2) clay, dark grayish brown (2.5Y 4/2) moist; weak medium and coarse prismatic structure parting to weak medium and fine blocky; very hard, very firm, sticky and plastic; common fine roots; strong effervescence; mildly alkaline; gradual wavy boundary.

B22--8 to 16 inches; grayish brown (2.5Y 5/2) clay, dark grayish brown (2.5Y 4/2) moist; weak, very coarse prismatic structure parting to moderate medium blocky; extremely hard, very firm, sticky and plastic; shiny pressure faces on surfaces of peds; few fine roots; strong effervescence; mildly alkaline; gradual wavy boundary. (Combined thickness of the B2 horizon is 8 to 28 inches.)

B3--16 to 24 inches; light olive gray (5Y 6/2) clay, dark grayish brown (2.5Y 4/2) moist; weak coarse subangular blocky structure parting to moderate medium and fine blocky; extremely hard, very firm, sticky and plastic; shiny pressure faces on surfaces of peds; few fine roots; strong effervescence; mildly alkaline; clear wavy boundary. (0 to 10 inches thick)

Clcs--24 to 40 inches; light olive gray (5Y 6/2) clay, olive gray (5Y 5/2) moist; weak medium subangular blocky structure in upper part becoming massive in lower part; extremely hard, very firm, sticky and plastic; common fine and medium nests of gypsum; strong effervescence; mildly alkaline; gradual boundary. (12 to 20 inches thick)

C2--40 to 60 inches; pale olive (5Y 6/3) clay, olive (5Y 5/3) moist; massive; very hard, firm, sticky and plastic; few fine accumulations of carbonate and gypsum; strong effervescence; mildly alkaline.

Type Location: Fall River County, South Dakota; about 6 miles east of Oelrichs; 450 feet west and 500 feet north of the SE corner (fence), north side of U. S. Highway 18, sec. 12, T. 10 S., R. 8 E.

Range in Characteristics: The thickness of the solum ranges from about 18 to 40 inches. The soil typically lacks free carbonates to depths of 4 to 6 inches, but some pedons contain carbonates at the surface. When the soil is dry, cracks 1/2 to 2 inches wide and several feet long extend downward through the solum. The control section typically averages about 60 percent clay. The soil lacks a mollic epipedon but the upper 10 inches of the solum has an average organic carbon content between 0.6 and 1.7 percent. When the soil is dry a porous crusty surface 1/8 inch to 1/2 inch thick with dry color value of 6 or 7 is typical.

The A horizon has hue of 10YR, 2.5Y, or 5Y, value of 5 or 6 and 3 or 4 moist, and chroma of 1 to 3. It typically is clay but some is silty clay. It is neutral or mildly alkaline.

KYLE SERIES--2

The B horizon has hue of 2.5Y or 5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 1 to 3. Both dry and moist colors of the surface of peds in the B2 horizons range from 1/2 to 1 value darker than the crushed peds. The B horizon has weak medium to very coarse prismatic structure that parts readily to weak or moderate, fine or medium subangular blocky or blocky. It is extremely hard or very hard when dry and extremely firm or very firm when moist. It is mildly or moderately alkaline.

The C horizon has hue of 2.5Y or 5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 or 3. In some pedons it has few or common, fine to coarse accumulations of carbonates which may also be in the B3 horizon. It has few or common accumulations of gypsum, and in some pedons the gypsum is in the B3 horizon. Unweathered shale typically is at depths greater than 5 feet but is as shallow as 40 inches in some pedons. It is mildly or moderately alkaline.

Competing Series: These are the Larvie, Pierre, Swanboy, Twotop, Wasa, and Winler series in the same family and the Hisle, Opal, and Promise series. The Larvie, Pierre, Wasa, and Winler soils have bedded shales within depths of 40 inches. Swanboy soils have visible salts within depths of 10 inches. Twotop soils lack prismatic structure. Hisle soils have natric horizons. The Opal and Promise soils have mollic epipedons.

Geographic Setting: Kyle soils are nearly level to moderately sloping on uplands and colluvial fans. Slopes are plane to convex, and slope gradients range from 0 to 9 percent. Slight gilgai microrelief is in some places. The soil formed in clay sediments weathered from calcareous clay shale. Mean annual air temperature ranges from 45 to 53° F, and mean annual precipitation ranges from about 12 to 17 inches.

Geographically Associated Soils: These are the competing Hisle, Pierre, Swanboy, Twotop, Wasa, and Winler soils and the Lismas and Samsil soils. Hisle soils are on similar landscapes with microrelief. Pierre soils are on landscapes above the Kyle soils. Swanboy soils are on fans and flats. Twotop, Wasa, and Winler soils are on similar landscapes below the Kyle soils. The Lismas and Samsil soils have shale within depths of 20 inches and are on steeper landscapes.

Drainage and Permeability: Well drained. Surface runoff is medium or rapid on sloping areas to slow on nearly level areas. Permeability is very slow, except after dry periods when the initial intake into cracks is rapid.

Use and Vegetation: Used primarily as rangeland. Wheat, sorghums, and alfalfa are principal crops when cultivated. Native grasses are mostly western wheatgrass, green needlegrass, buffalograss, and blue grama.

Distribution and Extent: Western South Dakota, northwest Nebraska, and eastern Wyoming. The series is extensive.

Series Established: Butte County, South Dakota, 1970.

Established Series  
Rev. CAM  
6/71

# McRAE SERIES

The McRae series is a member of the fine-loamy, mixed, mesic family of Ustollic Camborthids. Typically, McRae soils have light brownish gray loam Ap horizons, grayish brown loam B2 horizons and pale olive calcareous loam C horizons with slight segregation of lime in the upper part.

Typifying Pedon: McRae loam - cultivated  
(Colors are for dry soil unless otherwise noted.)

- Ap 0-5"--Light brownish gray (2.5Y 6/2) loam, dark grayish brown (2.5Y 4/2) moist; coatings on granules of grayish brown (2.5Y 5/2) dry and very dark grayish brown (2.5Y 3/2) moist; weak medium granular structure; slightly hard, very friable, slightly sticky, nonplastic; abrupt boundary.
- B2 5-11"--Grayish brown (2.5Y 5/2) loam, dark grayish brown (2.5Y 4/2) moist; coatings on peds of dark grayish brown (2.5Y 4/2), very dark grayish brown (2.5Y 3/2) moist; moderate medium prismatic structure; hard, very friable, slightly sticky, slightly plastic; thin patchy clay films; clear boundary. (6 to 9 inches thick)
- Clca 11-34"--Pale olive (5Y 6/3) loam, olive (5Y 5/3) moist; very weak coarse prismatic structure in upper part, becoming massive and stratified in lower part; hard, friable, slightly sticky, slightly plastic; moderate effervescence with few seams and soft nodules of segregated lime; gradual boundary. (20 to 30 inches thick)
- C2 34-60"--Pale olive (5Y 6/3) loam, olive (5Y 5/3) moist; massive; slightly hard, friable, slightly sticky, slightly plastic; moderate effervescence.

Type Location: Yellowstone County, Montana; 1350 feet south and 330 feet east of W1/4 corner sec. 19, T.4N., R.33E.

Range in Characteristics: The McRae soils are usually dry between depths of 4 and 12 inches but are not dry in all parts above 12 inches for more than half the time that soil temperature at 20 inches is more than 41°F. The mean annual soil temperature is about 48°F. The solum is 11 to 14 inches thick. The soil between depths of 10 and 40 inches is loam or light clay loam with 18 to 30 percent clay and more than 15 percent fine and coarser sands. The soil is moderately or strongly alkaline. Conductivity of the saturation extract ranges from 1 to 3 millimhos per cm. These soils are generally nonsaline. The Ap and B2 horizons are noncalcareous or weakly calcareous. Hue is 10YR through 5Y. The Ap horizon has value of 5 or 6 dry and 3.5 through 5 moist. Its granules are coated one-half to one unit of value darker. The B2 horizon has dry and moist value of the crushed soil the same as in the Ap horizon, and has coated colors one-half unit darker. The chroma is 2 or 3. The C horizon has value of 5 or 4 moist. It has less than 5 percent mottles of segregated lime and has an estimated 8 to 12 percent CaCO<sub>3</sub> equivalent.

Competing Series and their Differentiae: These are the Edgar and Menoken series. Edgar soils have a prominent horizon of lime accumulation with dry value of 7 or more. Menoken soils have less than 15 percent fine and coarser sand in the 10- to 40-inch control section.

Setting: McRae soils are on terraces of rivers and streams, alluvial fans in valleys, and footslopes in the uplands. They formed in calcareous loam alluvium from soils developed over sedimentary rocks. The mineralogy of the alluvium is mixed. The climate is semiarid with a mean annual precipitation of 8 to 14 inches and mean annual temperature of 45° to 50°F.

Principal Associated Soils: These are the Bainville, Cushman, Elso, Fort Collins, Havre, and Midway soils. Bainville, Cushman, Elso and Midway soils are on the uplands occupying hills and ridges, and the Fort Collins and Havre soils are in valleys. Bainville, Cushman, Elso and Midway soils have shale bedrock at depths ranging shallower than 40 inches, and Cushman and Fort Collins soils have Bt horizons. Havre soils occur on river and stream flood plains and have no horizonation.

Drainage and Permeability: Well-drained; moderate permeability; slow to medium runoff.

Use and Vegetation: Principally used for irrigated cropland. Used also for rangeland. Principal native vegetation is mixed short and mid grasses and forbs.

McRae Series

Distribution and Extent: Southeastern Montana where they are moderately extensive.

Series Established: Treasure County, Montana, 1961.

Remarks: The McRae soils were formerly classified as Brown soils.

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Established Series  
Rev. CAM/JLP  
10/75

#### MIDWAY SERIES

The Midway series consists of shallow, well drained soils that formed in material weathered from shale. Midway soils are on convex crests of ridges and hills and have slopes of 2 to 75 percent. The mean annual precipitation is about 12 inches, and the mean annual air temperature is about 46°F.

Taxonomic Class: Clayey, montmorillonitic (calcareous), mesic, shallow Ustic Torriorthents.

Typical Pedon: Midway silty clay loam, grassland. (Colors are for dry soil unless otherwise noted.)

A1--0 to 3 inches; light yellowish brown (2.5Y 6/4) silty clay loam, light olive brown (2.5Y 5/4) moist; weak thin plates that separate to fine crumb structure; soft, friable, sticky and plastic; many very fine roots and pores; strongly effervescent; moderately alkaline (pH 8.4); gradual boundary. (2 to 8 inches thick)

AC--3 to 7 inches; light yellowish brown (2.5Y 6/4) clay, light olive brown (2.5Y 5/4) moist; thin platy structure; soft, friable, sticky and plastic; many very fine roots and pores; strongly effervescent; moderately alkaline (pH 8.0); abrupt boundary. (2 to 8 inches thick)

C1--7 to 14 inches; light brownish gray (2.5Y 6/3) mottled with light gray (2.5Y 7/2) clay, light olive brown (2.5Y 6/3) and olive (5Y 5/3) moist; thin platy structure with gypsum crystals between the plates; soft, friable, sticky and plastic; many very fine roots with few roots and tubular pores through soft shale plates; strongly effervescent; moderately alkaline (pH 8.0); abrupt boundary. (2 to 8 inches thick)

C2r--14 to 30 inches; pale olive (5Y 6/3) platy silty and clayey shale mottled with yellow, brown and black, with seams of gypsum crystals; few roots in vertical cracks of shale; strongly effervescent; moderately alkaline (pH 8.4).

Type Location: Powder River County, Montana; 300 feet south and 200 feet east of N1/4 corner of section 23, T.3S., R.49E.

Range in Characteristics: Mean annual soil temperature ranges from 47° to 50°F. The depth to the paralithic contact of stratified shale beds is 6 to 20 inches. The hue ranges from 10YR through 5Y. The control section is clay, silty clay, or silty clay loam with 35 to 45 percent clay.

The A horizon has value of 3 through 6 dry, 2 through 5 moist, and chroma of 2 or 3. Horizons with value of 3 dry and 2 moist are thin (1 to 4 inches thick). This horizon is neutral to moderately alkaline.

The C horizon has value of 5 through 8 dry, 4 through 6 moist, and chroma of 2 through 4.

Competing Series: These are the Chantier, Danko, Epsie, Lismas and Samsil series in the same family, and the Lisam and Wayden series that are closely related. Chantier soils have B2 and Ccssa horizons. Danko soils have hue of 7.5YR or redder. Epsie soils have 50 to 60 percent clay. Lismas soils contain 45 percent clay. Samsil soils have more than 50 percent clay, more than 35 percent shale fragments of sand and silt size in the control section and have low clay activity relative to total clay. Lisam and Wayden soils have soil temperatures of 47°F. or less.

Geographic Setting: Midway soils are gently sloping to very steep and are on crests of ridges and hill sides of sedimentary plains, at elevations of 2,300 to 3,500 feet. They formed in material weathered from calcareous platy shale in which the clay is mostly of montmorillonitic type. The climate is semiarid. The mean annual temperature is 46° to 50°F. The mean annual precipitation is 8 to 16 inches, most of which falls during spring and early summer. The 32°F. growing season is 115 to 140 days.

Geographically Associated Soils: These are the Bainville, Oceanet, Razor, Renohill, Shingle, Thurlow, and Travessilla soils, and the competing Lismas soils. Bainville soils have siltstone bedrock at depth of about 24 inches. Oceanet soils have 5 to 18 percent clay in the control section. Razor, Renohill, and Thurlow soils have heavy clay loam or clay B horizon. Shingle soils have less than 35 percent clay in the control section. Travessilla soils have hard sandstone bedrock at depth of about 8 inches.

Drainage and Permeability: Well drained; medium to rapid runoff; slow permeability.

Use and Vegetation: Principally native range with associations of short grasses or forbs--prairie junegrass, silver sage, threadleaf sedge, western wheatgrass and rabbitbrush. Some areas have low density stands of ponderosa pine.

Distribution and Extent: Montana, Colorado, and western North Dakota. The series is moderately extensive.

Midway Series

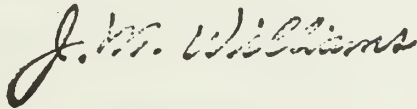
Series Established: Central Montana Reconnaissance, Montana, 1946.

Remarks: The Midway soils were formerly classified as Lithosols.

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APPROVED BY PRINCIPAL SOIL CORRELATOR  
WEST REGIONAL TSC, 12/7/71

Established Series  
Rev. AJC  
12/71



OCEANET SERIES

The Oceanet series is a member of the loamy, mixed (calcareous), mesic, shallow family of Typic Torriorthents. Typically, Oceanet soils have very friable calcareous A horizons, and calcareous moderately coarse textured C horizons overlying bedrock.

Typifying Pedon: Oceanet loam - grassland  
(Colors are for dry soil unless otherwise noted.)

- Al 0-5"--Light brownish gray (2.5Y 6/3) sandy loam, dark grayish brown (2.5Y 4/2) moist; weak fine crumb structure that parts to single grains; soft, very friable; calcareous; moderately alkaline (pH 8.2); gradual smooth boundary. (4 to 6 inches thick)
- C 5-14"--Light yellowish brown (2.5Y 6/3) sandy loam, light olive brown (2.5Y 5/3) moist; massive; slightly hard, very friable; many partially weathered sandstone fragments soft enough to be crushed in the hand; calcareous; moderately alkaline (pH 8.4); gradual wavy boundary. (4 to 12 inches thick)
- IIC 14-20"--Calcareous sandstone.

Type Location: Fremont County, Wyoming; approximately 550 feet N and 200 feet E of the W 1/4 corner of sec. 34, T.3N., R.3E.

Range in Characteristics: They are calcareous at or near the surface.

Depth to bedrock ranges from 10 to 20 inches. Content of organic carbon in the surface horizon ranges from .5 to 2 percent and decreases uniformly with depth. Conductivity is typically less than 1 millimho and E. S. P. is typically less than 1 percent in the control section, but both may increase slightly just above the bedrock. The control section is typically a sandy loam, but clay may range from 5 to 18 percent, silt from 5 to 35 percent, and sand from 52 to 80 percent with more than 35 percent fine sand or coarser, and excluding loamy fine sand or coarser texture. Content of coarse fragments range from 0 to 35 percent and are mostly sandstone channery. Mean annual

### Oceanet Series

soil temperature ranges from 47° to 50°F., and mean summer soil temperature ranges from 60 to 75°F. The A horizon has hue of 5Y through 10YR, value of 5 or 6 dry and 4 or 5 moist, and chroma of 2 or 3. Reaction ranges from pH 8.0 to pH 8.6. Usually structure is granular or crumb, but it is weak subangular blocky or single grained in some pedons. Dry consistence ranges from soft to slightly hard. Hue of the C horizon ranges from 5Y through 10YR. Reaction ranges from pH 8.0 to pH 8.6, and calcium carbonate equivalent ranges from 1 to 3 percent with no continuous horizons of visible secondary carbonate accumulation.

Competing Series and their Differentiae: These are the Birdsley, Persayo, and Roic. Birdsley and Persayo soils have more than 18 percent clay in the control section. Roic soils have less than 35 percent fine and coarser sand in the control section.

Setting: These soils are on gently to steeply sloping upland hills and ridges with slope gradients ranging from 1 to 40 percent. The regolith consists of moderately coarse textured, calcareous sediments weathered from the underlying bedrock. At the type location, the average annual precipitation is 7 inches, with peak periods of precipitation during the spring and summer months. Mean annual soil temperature is 48°F., mean summer soil temperature is about 67°F.

Principal Associated Soils: These include the Apron and Worland soils. Apron soils lack bedrock within 40 inches of the surface. Worland soils have bedrock between depths of 20 and 40 inches.

Drainage and Permeability: Well and somewhat excessively drained; runoff is slow; permeability is rapid to moderately rapid.

Oceanet Series

Use and Vegetation: These soils are used principally as rangeland. Native vegetation includes sage, Indian ricegrass, needle-and-thread, and some blue grama.

Distribution and Extent: Basin areas of north and central Wyoming. The series is of moderate extent.

Series Established: Fremont County (Riverton Irrigated Area), Wyoming, 1969.

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REVISED DRAFT

Tentative Series  
CAM-JLP 9/30/66

RAPELJE SERIES

The Rapelje series is a member of a fine-silty, mixed, frigid family of Borollic Glossic Natrargids. Typically, these soils have A2, A&D, Bt, Bcs, Cca and C horizon sequence with much clear unstained silt and sand grains coating peds in A2 and upper Bt horizons.

Typifying Pedon: Rapelje silt loam, native grass cover  
(Colors are for dry soil unless otherwise noted.)

- A2 0-5"--Light brownish gray (10YR 6/2) top of plates and grayish brown (10YR 5/2) on bottom of plates, silty loam; dark grayish brown (10YR 4/2) moist; many clean silt grains; weak fine platy structure; soft, friable, slightly sticky; abundant fine roots; noncalcareous; pH 6.5; clear boundary. (3 to 7 inches thick)
- A&B 5-8"--Light brownish gray (10YR 6/2) top and vertical faces of peds, dark grayish brown (10YR 4/2) of ped interior, silty clay loam; dark brown, crushing to dark grayish brown (10YR 3/3 and 4/2) moist; weak prismatic breaking to moderate fine blocky structure; hard, friable, sticky and plastic; clay coating and bridging mineral grains through soil with many clean silt grains on ped tops and vertical faces; abundant fine roots; noncalcareous; pH 6.5; clear smooth boundary. (2 to 6 inches thick)
- B2t 8-18"--Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2, crushed 4/2) moist; moderate medium and coarse prismatic separating to strong medium blocky structure; hard, friable, sticky and plastic; prominent clay film on peds; few gypsum crystals in lower portion of horizon; common fine roots between peds; noncalcareous, pH 7.0; clear boundary. (4 to 16 inches thick)
- B3cs 18-26"--Mixed pale brown (10YR 6/3) and brown (10YR 5/3) silty clay loam, dark brown (10YR 4/3) when moist and crushed; moderate fine blocky structure; hard, friable, sticky, plastic; prominent clay film on peds; few to common seams of gypsum; few fine roots; strongly calcareous, pH 8.0; gradual smooth boundary. (5 to 12 inches thick)
- Clca 26-43"--Light gray (10YR 7/2) silt loam, grayish brown (10YR 5/2) moist; massive; hard, friable, slightly sticky and nonplastic; strongly calcareous; pH 8.0; few seams and threads of lime; very few fine roots; gradual smooth boundary. (10 to 20 inches thick)
- IIC2 43-60"--Light gray (10YR 7/2) fine sandy loam, brown (10YR 5/3) moist; single grain; soft, very friable, no roots; strongly calcareous; pH 8.0.

Type Location: Powder River County, Montana; 600 feet west and 600 feet north of SE corner, Section 23, T6S, R46E.

## Rapelje Series

Range in Characteristics: Rapelje soils are usually dry when not frozen, unless irrigated. Mean annual soil temperature is less than 47 degrees F. and average summer temperature is warmer than 60 degrees F. Soil colors are in hues of 10YR to 5Y. The A2 horizon has dry values of 6 to 7 and moist values of 3 to 5, chroma are 2 or 3. Structure is weak platy and weak prismatic separating to weak thick platy. The mixed A&B horizon is more clayey than the A2 horizon, has the same range in color and has a weak prismatic structure separating to thick platy or fine blocky structure. The B2t horizon is darker colored with dry values of 4 to 6 and moist values of 3 to 4 with chroma of 2. Structure is prismatic separating to moderate or strong blocky. Peds have light reflecting surfaces when dry indicating presence of clay film. Percent of clay in the B2t ranges from 25 to 35 percent with from 5 to 10 absolute percent more clay than in the A2 horizon. Crystals of  $\text{CaSO}_4$  appear in the lower B2t horizon, are common or abundant in Bcs or Ccs horizon. The C horizon is a silt loam with from 15 to 27 percent clay, has 5 to 10 percent  $\text{CaCO}_3$  equivalent with few to common segregations of calcium carbonate.

Competing Series and Their Differentiae: These include the Hydro series in a different family of the same subgroup and the Phillips series in a different Great Group. These competing series have A2, A&B, B2t sequence of horizons in their solums. The Hydro series has more than 35 percent clay in the B2t horizon and the mean annual soil temperature is warmer than 47 degrees F. The Phillips series has more than 35 percent clay, less than 5 percent exchangeable sodium and a wide calcium to magnesium exchange ratio in the B2t horizon.

Setting: The Rapelje soils occur on nearly level to sloping upland plains in southeastern Montana at elevations ranging from 3,000 to 4,000 feet. Parent materials are weathered calcareous siltstone or locally transported silt loam materials. The climate is cool semiarid with 10 to 16 inches average annual precipitation, mean annual temperature of 42 to 45 degrees F., and average summer temperature of 65 to 70 degrees F.

Principal Associated Soils: These include the Farland and Cabba series. The Farland soils have dark colored Al horizons and B2t horizons developed in deep silt loam deposits. The Cabba soils are light colored and have soft loam or silt loam bedrock at depths shallower than 20 inches.

Drainage and Permeability: Rapelje are well drained soils with moderately slow permeability.

Use and Vegetation: Used for native rangeland and for production of small grains. Native vegetation consists of green needlegrass, needleandthread, western wheatgrass, upland sedges and sagebrush.

Distribution and Extent: Rapelje soils are moderately extensive in southeastern Montana.

Series Proposed: Power River Area Soil Survey, Montana, 1966.

Remarks: This series was formerly classified with Solodized-Solonetz soils.

Established Series  
Rev. CAM/JLP  
4/72

#### REMMIT SERIES

The Remmit series is a member of the coarse-loamy, mixed, mesic family of Ustollic Camborthids. Typically, Remmit soils have grayish brown fine sandy loam A1 and B2 horizons and light olive brown calcareous fine sandy loam C1 horizons resting on grayish brown calcareous heavy silt loam IIC2ca horizons.

Typifying Pedon: Remmit fine sandy loam - native grass  
(Colors are for dry soil unless otherwise noted.)

- A1 0-12"--Grayish brown (10YR 5/2) fine sandy loam, dark grayish brown (10YR 4/2) coated with very dark grayish brown (10YR 3/2) moist; weak crumb structure; soft, very friable, nonsticky, nonplastic; many very fine roots and fine interstitial pores; noncalcareous; neutral (pH 7.3); gradual boundary. (7 to 15 inches thick)
- B2 12-24"--Grayish brown (2.5Y 5/2) fine sandy loam, dark grayish brown (2.5Y 4/2) moist; weak prismatic structure; soft, very friable, nonsticky, nonplastic; few roots; noncalcareous; mildly alkaline (pH 7.5); gradual boundary. (5 to 15 inches thick)
- C1 24-44"--Light olive brown (2.5Y 4/2) fine sandy loam with numerous small sandstone and siltstone chips, olive brown (2.5Y 4/4) moist; massive; slightly hard, very friable, nonsticky, nonplastic; few roots; mildly calcareous; moderately alkaline (pH 8.4); abrupt boundary.
- IIC2ca 44-62"--Grayish brown (2.5Y 5/2) heavy silt loam, dark grayish brown (2.5Y 4/2) moist; massive; slightly hard, friable, slightly sticky, slightly plastic; few roots; moderately calcareous; white (2.5Y 8/2) lime segregstions, light brownish gray (2.5Y 6/2) moist; strongly alkaline (pH 9.0).

Type Location: Powder River County, Montana; 1,100 feet south and 1,300 feet east of NE section corner of sec. 25, T.2S., R.50E.

Range in Characteristics: The mean annual soil temperature is 48° to 52°F. The hue is yellower than 7.5YR. B2 and upper C horizons are fine sandy loam or sandy loam. The A1 horizon has value of 3.5 to 5 and chroma of 2 or 3. The B horizon has moist value of 4 or 5 and chroma of 2 through 4. The weighted average organic carbon content in the upper 15 inches is .7 to 1 percent. The sand/clay ratio ranges from 4 to 10. Estimated CaCO<sub>3</sub> equivalent is 8 to 12 percent in the Cca horizons.

Competing Series and their Differentiae: These are the Alice, Begay, Ignacio, McRae, Terry, Twilight, Vona and Wall series. Alice soils have mollic epipedons. Begay soils have hue of 5YR or 7.5YR in the B2 horizon. Ignacio soils have a lithic contact at depths of 20 to 40 inches. McRae soils have 18 to 30 percent clay in the 10- to 40-inch control section. Terry and Vona soils have argillic horizons and Terry soils have sandstone at a depth of about 28 inches. Twilight soils have mean annual soil temperature colder than 47°F. Wall soils average less than .5 percent organic carbon in the upper 15 inches.

Setting: Remmit soils occupy smooth slopes on the undulating to hilly uplands on soft sandstone residual plains. The parent material is weathered calcareous soft massive sandstone or transported materials of mixed mineralogy. The climate is cool semiarid with a mean annual temperature of 45° to 50°F. and mean summer temperature warmer than 65°F. Mean annual precipitation is 10 to 15 inches with 6 to 8 inches falling during May through September.

Principal Associated Soils: These are the Oceanet, Travessilla, and Tullock soils and the competing Vona soils. Oceanet and Travessilla soils have sandstone bedrock at depths of 10 to 20 inches. Tullock soils have sandstone bedrock at depths of 20 to 40 inches.

Drainage and Permeability: Well-drained; moderately rapid permeability.

Use and Vegetation: Used for dryland crops of small grains and hay or for native range. Vegetation is mid and tall grasses, green needlegrass, prairie sandreed, yucca, lupine, onion and cacti.

Remmit Series

Distribution and Extent: Remmit soils occur in southeastern Montana where the series is inextensive.

Series Established: Powder River County (Powder River Area), Montana, 1972.

Remarks: Remmit soils were formerly classified as Brown soils.

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Established Series  
Rev. JCM/CAM  
6/73

## RINGLING SERIES

The Ringling series is a member of the fragmental, mixed family of Typic Haploborolls. Typically, Ringling soils have reddish brown channery loam A1 horizons, and reddish brown very channery loam C horizons with the volume of rock fragments increasing with increasing depth from 35 to 80 percent and grading to loose porcellanite or burned shale and sandstone bedrock at a depth of about 13 inches.

Typifying Pedon: Ringling channery loam - native sod cover  
(Colors are for dry soil unless otherwise noted.)

- A1 0-3"--Reddish brown (5YR 4/4) channery loam, dark reddish brown (5YR 3/3) moist; weak fine crumb structure; soft, very friable, nonsticky, nonplastic; many very fine roots; many very fine interstitial pores; 30 percent thin hard burned shale fragments; neutral; clear wavy boundary. (3 to 8 inches thick)
- C1 3-13"--Reddish brown (5YR 5/3) very channery loam, dark reddish brown (5YR 3/3) moist; massive; soft, very friable, nonsticky, nonplastic; many very fine roots; 35 percent increasing with increasing depth to 80 percent flat fragments of hard baked shale; neutral; abrupt boundary. (0 to 15 inches thick)
- C2 13-60"--Hard platy red baked shale coated with lime and having pendants of lime on undersides; soil from C1 horizon partly fills the voids between rock fragments in the upper part.

Type Location: Big Horn County, Montana; 525 feet SE of center sec. 17, T.5S., R.38E.

Range in Characteristics: Depth to fractured bedrock ranges from 5 to 20 inches. Rock fragments range from 30 percent in the A1 horizon to as much as 80 percent in the lower C1 horizon. Lime coating occurs on rock fragments in places but the loam matrix is noncalcareous. The underlying shale is noncalcareous in some pedons. The A1 horizon has hue of 7.5YR through 10R, value of 4 or 5 dry, and chroma of 2 or 3 moist. Mean annual soil temperature ranges from 44° to 47°F. Average summer soil temperature ranges from 60° to 64°F.

Competing Series and their Differentiae: These are the Castner, Cathedral, Comodore, Maginnis, and Wibaux soils. All of these soils except Wibaux have a lithic contact at depths of 20 inches or less. Also, Castner soils have a Cca horizon and Maginnis soils have 2.5Y or 10YR hue and have clay texture. Wibaux soils lack mollic epipedons, are usually dry, and have mean annual soil temperature of about 47°F.

Setting: Ringling soils are on strongly rolling or steeply sloping uplands. They formed in residuum weathered from hard red baked shale or porcellanite rocks in areas having 13 to 16 inches mean annual precipitation with mean annual soil temperature ranging from 44° to 46°F, and mean summer soil temperature higher than 60°F.

Principal Associated Soils: These are the Barvon, Bitterroot, Danvers, and Judith soils. Barvon and Bitterroot soils have mollic epipedons and paralithic contacts. Danvers and Judith soils are very deep soils on old alluvial deposits.

Drainage and Permeability: Well-drained; rapid permeability.

Use and Vegetation: Ringling soils are used entirely for range. Native vegetation is bluebunch wheatgrass, Idaho fescue, Sandberg bluegrass, and annuals with scattered to dense stands of western yellow pine.

Distribution and Extent: Ringling soils are widely distributed on the higher elevations of the residual shale plains in southeastern Montana. They are moderately extensive.

Series Established: Reconnaissance Soil Survey of Central Montana, 1946.

Remarks: The Ringling soils were formerly classified as Lithosols.

National Cooperative Soil Survey  
U. S. A.



THURLOW SERIES

The Thurlow series is a member of the fine, montmorillonitic, mesic family of Ustollic Haplargids. Typically, Thurlow soils have grayish brown loam A1 horizons, brown clay loam B2t horizons with the maximum amount of clay in the upper part and light yellowish brown calcareous clay loam C horizons with slight amount of segregated lime in the Cca horizons.

Typifying Pedon: Thurlow clay loam - native grass cover  
(Colors are for dry soil unless otherwise noted.)

- A1 0-4"--Grayish brown (10YR 5/2) heavy loam, dark grayish brown (10YR 4/2) moist; weak thin platy structure in the upper part and moderate thin structure in the lower part; slightly hard, friable, slightly sticky, slightly plastic; many very fine roots; many clear unstained sand grains on tops of plates; clear smooth boundary. (2 to 6 inches thick)
- B2t 4-16"--Brown (10YR 5/3) heavy clay loam, dark brown (10YR 4/3) moist; dark grayish brown (10YR 4/2) coating on peds, dark brown (10YR 3/3) moist; moderate medium prismatic structure that separates to strong medium blocks; very hard, firm, sticky, plastic; common very fine roots; many very fine and common fine tubular pores; varnish-like coating on peds and on walls of pores and root channels, with some pores having rounded edges; maximum clay content is in the upper part of the horizon; clear boundary. (6 to 16 inches thick)
- C1ca 16-28"--Light yellowish brown (2.5Y 6/3) clay loam, light olive brown (2.5Y 5/3) moist; prisms coated slightly darker in the upper part; moderate medium prismatic grading to weak coarse prismatic structure that separates to weak coarse blocks; hard, friable, sticky, plastic; common very fine roots; common very fine and fine tubular pores; calcareous with common films of segregated lime; gradual boundary. (8 to 20 inches thick)
- C2 28-60"--Light yellowish brown (2.5Y 6/3) stratified clay loam and clay, light olive brown (2.5Y 5/3) moist; massive; hard, friable, sticky plastic; few very fine roots; common very fine tubular pores; calcareous.

Type Location: Yellowstone County, Montana; 1,200 feet north of SE corner section 19, T.2N., R.28E.

Range in Characteristics: Thurlow soils are usually dry when not frozen unless irrigated and they have mean annual soil temperature of 47° to 50°F. The noncalcareous part of the solum is 10 to 20 inches thick. Hue is 10YR or 2.5Y. The A1 or Ap horizon has value of 5 or 5.5 dry and 3.5 or 4 moist, and chroma of 2 or 3. In its upper part coated colors are one unit of value less than when crushed and less than that of the A1 or Ap horizon. The B2t horizon has dry value of 4 or 5 coated and 5 or 6 crushed, moist value of 4 or 5 crushed and chroma of 2 through 4. It contains 35 to 45 percent clay and has 6 to 10 percent more clay than the Ap or A1 horizon and is highest in clay in the upper part.

Competing Series and their Differentiae: These are the Baca, Bew, Fort Collins, Hesper, and Renohill series. Baca and Hesper soils have less than 18 percent fine and coarser sand in their pedons. Bew soils have 50 to 60 percent clay in their Bt horizons. Fort Collins soils have less than 35 percent clay in the B2t horizon. Renohill soils have shale bedrock at depths of about 30 inches.

Setting: The Thurlow soils are mainly in valleys on river and stream terraces. The soils formed in calcareous, clay loam, unconsolidated materials. Climate is cool semiarid with mean annual temperature of 45° to 48°F., mean summer temperature of more than 62°F. mean winter temperature 20° to 28°F. Mean annual precipitation is 10 to 13 inches.

Principal Associated Soils: These are the Arvada, and Hydro soils and the competing Bew and Fort Collins soils. Arvada and Hydro soils have natric horizons.

Drainage and Permeability: Well-drained; moderately permeable.

Use and Vegetation: Used mainly for irrigated production of diversified crops, nonirrigated production of small grains and native range of mid and short grasses--mainly blue grama and western wheatgrass.

Thurlow Series

Distribution and Extent: Thurlow series is moderately extensive in southeastern Montana.

Series Established: Big Horn County (Big Horn Area), Montana, 1970.

Remarks: Thurlow soils were formerly classified as Brown soils.

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Established Series  
Rev. AJC  
10/71

VONA SERIES

The Vona series is a member of the coarse-loamy, mixed, mesic family of Ustollic Haplargids. Typically, Vona soils have very friable granular A horizons, moderately coarse textured B<sub>2t</sub> horizons, and weak to moderate horizons of secondary calcium carbonate accumulation.

Typifying Pedon: Vona fine sandy loam - range  
(Colors are for dry soil unless otherwise noted.)

- A1 0-5"--Light brownish gray (10YR 6/2) light sandy loam, dark grayish brown (10YR 4/2) moist; moderate fine granular structure; soft, very friable; neutral (pH 7.0); clear smooth boundary. (4 to 8 inches thick)
- A3 5-8"--Brown (10YR 5/3) light sandy loam, brown or dark brown (10YR 4/3) moist; weak medium subangular blocky structure that parts to moderate medium granules; slightly hard, very friable; neutral (pH 7.0); clear smooth boundary. (3 to 4 inches thick)
- B<sub>2t</sub> 8-24"--Brown (10YR 5/3) sandy loam, dark brown (10YR 4/3) moist; weak very coarse prismatic structure parting to moderate coarse subangular blocks; hard, friable, thin patchy clay films on both horizontal and vertical faces of peds, and clay bridging between sand grains; neutral (pH 7.2); clear smooth boundary. (5 to 22 inches thick)
- B<sub>3ca</sub> 24-30"--Pale brown (10YR 6/3) light sandy loam, brown (10YR 5/3) moist; weak and moderate coarse subangular blocky structure; slightly hard, very friable; few thin patchy clay films and a small amount of clay bridging between sand grains; some visible secondary calcium carbonate occurring as small concretions; calcareous; moderately alkaline (pH 8.2); gradual wavy boundary. (3 to 6 inches thick)
- C<sub>1ca</sub> 30-50"--Very pale brown (10YR 7/3) light sandy loam, brown (10YR 5/3); moist; massive; slightly hard, very friable; some visible secondary calcium carbonate occurring as small concretions, and in thin seams and streaks; calcareous; moderately alkaline (pH 8.2); gradual wavy boundary. (6 to 20 inches thick)
- C<sub>2ca</sub> 50-60"--Pale brown (10YR 6/3) loamy sand, yellowish brown (10YR 5/4) moist; single grained; slightly hard and loose, very friable; small amount of secondary calcium carbonate but less than in the horizon above; calcareous; moderately alkaline (pH 8.2). (Several feet thick)

Type Location: Morgan County, Colorado; approximately 1,700 feet south and 1,000 feet east of the northwest corner of sec. 22, T.5N., R.59W.

Range in Characteristics: Depth to calcareous material ranges from 8 to 24 inches, thickness of solum ranges from 15 to 40 inches. Weighted average content of organic carbon in the upper 15 inches exceeds .5 percent and decreases uniformly with depth. Content of coarse fragments ranges from 0 to 15 percent. Mean annual soil temperature is 49 to 54 degrees F. The A horizon has hue of 2.5Y or 10YR, chroma of 2 or 3, and value of 5 or 6 dry and 3 through 5 moist. It is neutral to mildly alkaline (pH 6.8 to 7.8). Typically, the horizon has granular or crumb structure but is single grained in some pedons. It is soft to slightly hard. The B<sub>2t</sub> horizon has hue of 2.5Y or 10YR, chroma of 2 through 4, and value of 5 or 6 dry and 4 or 5 moist. It is neutral to mildly alkaline (pH 7.0 to 7.8). This horizon is typically sandy loam with clay ranging from 8 to 18 percent, silt from 5 to 35 percent, and sand from 52 to 85 percent with more than 35 percent fine sand or coarser. The C horizon has hue of 2.5Y or 10YR. It is moderately to strongly alkaline (pH 8.0 to 8.6), and the calcium carbonate equivalent ranges from 2 to 12 percent.

Competing Series and their Differentiae: These are Bijou, Gilcrest, Neeapah, Palma, and Terry series. Bijou soils lack a C<sub>ca</sub> horizon. Gilcrest soils have 15 to 30 percent gravel in the solum. Neeapah soils have a nitrogen and phosphate enriched man-made Ap horizon more than 7 inches thick. Palma soils have hue of 7.5YR or redder. Terry soils have a lithic contact at depths of 20 to 40 inches.

Setting: The Vona soils are on gently to moderately sloping uplands frequently paralleling major river channels. Slope gradient ranges from 0 to about 12 percent. The soils formed in eolian or partly wind reworked alluvial parent materials. At the type location the average annual precipitation is 14 inches, 10 inches of which falls during the months of April through September. The average annual temperature is 50 degrees F., and the average summer temperature is 70 degrees F.

Vona Series

Principal Associated Soils: These are the competing Terry soils and the Otero, Olney, Valentine, and Ascalon soils. Ascalon soils have a mollic epipedon. Olney soils have a fine-loamy control section. Otero soils lack an argillic horizon. Valentine soils have sandy control sections and lack an argillic horizon.

Drainage and Permeability: Well to somewhat excessively drained; slow runoff; rapid permeability.

Use and Vegetation: These soils are used as dry and irrigated cropland, as well as native pastureland. Native vegetation consists of short and tall grass associations.

Distribution and Extent: Eastern Colorado, southeastern Wyoming and Montana. The series is extensive.

Series Established: Washington County (Akron Area), Colorado, 1947.

Remarks: This series is characterized by sample S61-Colo-44-1-(1-6).

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Table 61  
Sheet 1 of 2

PUMPKIN CREEK  
INTERPRETIVE RATINGS FOR SOIL USES

Map Symbol (SCS) (1)	Soil Name (2)	Suitability						Degree of Limitation				
		Dryland Farming (3)	Irrigation (4)	Topsoil (5)	Sand/ Gravel (6)	Road Fill (7)	Range/ Wildlife (8)	Ponds		Road Location (11)	Shallow Excavations (12)	Building Sites (13)
								Location (9)	Embankment (10)			
Ab	Arvada - Bone, 0-4%	Poor	Poor	Poor	Poor	Poor	Good	Slight	Severe	Severe	Severe	Severe
Be	Bew, 2-4%	Fair	Fair	Poor	Poor	Poor	Good	Slight	Severe	Severe	Severe	Severe
Bw	Bew, 4-8%	Fair	Fair	Poor	Poor	Poor	Good	Slight	Severe	Severe	Severe	Severe
Ce	Cushman- Elso, 4-8%	Poor-Fair	Fair	Fair	Poor	Poor	Good	Severe	Moderate	Moderate	Moderate	Severe
Ch	Cushman- Elso, 8-15%	Poor-Fair	Poor-Fair	Fair	Poor	Poor	Good	Severe	Moderate	Moderate	Moderate	Severe
Ec	Elso, 8-15%	Poor	Poor	Poor	Poor	Poor	Good	Severe	Moderate	Moderate	Mod-Sev.	Severe
E1	Elso, 15-45%	Poor	Poor	Poor	Poor	Poor	Good	Severe	Moderate	Severe	Severe	Severe
Fd	Farland, 2-4%	Fair-Good	Good	Good	Poor	Poor	Good	Moderate	Moderate	Slight	Slight	Severe
Fr	Fort Collins, 2-4%	Fair-Good	Good	Good	Poor	Poor	Good	Slight	Moderate	Moderate	Slight	Severe
Ga	Galata, 4-8%	Poor-Fair	Poor	Poor	Poor	Poor	Good	Moderate	Severe	Severe	Severe	Severe
He	Haverson 0-2%	Fair-Good	Good	Good	Poor	Poor	Good	Moderate	Slight- Moderate	Moderate	Slight	Severe
Hk	Heldt, 2-4%	Fair-Good	Fair	Fair	Poor	Fair	Good	Moderate	Moderate	Moderate	Slight	Mod-Sev
hn	Hesper, 0-2%	Fair-Good	Good	Good	Poor	Poor	Good	Slight	Moderate	Moderate	Slight	Severe
Ho	Hesper, 2-4%	Fair-Good	Good	Good	Poor	Poor	Good	Slight	Moderate	Moderate	Slight	Severe
Hp	Hesper, 4-8%	Fair-Good	Fair-Good	Good	Poor	Poor	Good	Slight	Moderate	Moderate	Slight	Severe
Hr	Hesper, 8-15%	Fair	Poor-Fair	Good	Poor	Poor	Good	Slight- Moderate	Moderate	Moderate	Moderate	Severe
Hs	Hopley- Relan, 4-8%	Fair	Fair	Good	Poor	Poor	Good	Moderate	Moderate	Moderate	Moderate	Severe
Ht	Hydro, 0-2%	Fair	Fair-Good	Fair	Poor	Fair	Good	Slight	Moderate- Severe	Moderate- Severe	Slight	Moderate- Severe
Hu	Hydro, 2-4%	Fair	Fair-Good	Fair	Poor	Fair	Good	Slight	Moderate- Severe	Moderate- Severe	Slight	Moderate- Severe
Hw	Hydro- Arvada, 2-8%	Poor-Fair	Poor-Fair	Poor	Poor	Poor	Good	Slight	Severe	Moderate- Severe	Moderate	Severe
Hx	Hydro- Elso, 8-15%	Poor-Fair	Poor-Fair	Poor	Poor	Poor	Good	Severe	Moderate- Severe	Moderate- Severe	Moderate	Severe
Hy	Hydro-Fort Collins, 0-2%	Fair-Good	Fair-Good	Fair	Poor	Fair	Good	Slight	Moderate- Severe	Moderate- Severe	Slight	Severe
Mc	McRae, 0-2%	Fair-Good	Good	Good	Poor	Poor	Good	Moderate	Moderate	Slight- Moderate	Slight	Severe
Md	McRae, 2-4%	Fair-Good	Good	Good	Poor	Poor	Good	Moderate	Moderate	Slight- Moderate	Slight	Severe

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Table 61  
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PUMPKIN CREEK  
INTERPRETIVE RATINGS FOR SOIL USES

Map Symbol (SCS) (1)	Soil Name (2)	Suitability						Degree of Limitation				
		Dryland Farming (3)	Irrigation (4)	Topsoil (5)	Sand/ Gravel (6)	Road Fill (7)	Range/ Wildlife (8)	Ponds		Road Location (11)	Shallow Excavations (12)	Building Sites (13)
								Location (9)	Embankment (10)			
Mf	Midway, 2-8%	Poor	Poor	Poor	Poor	Fair	Good	Severe	Severe	Severe	Moderate	Severe
Mg	Midway-Elso 8-35%	Poor	Poor	Poor	Poor	Fair	Good	Severe	Severe	Severe	Moderate- Severe	Severe
Mr	Midway- Rockland, 15-35%	Poor	Poor	Poor	Poor	Poor	Good	Severe	Severe	Severe	Severe	Severe
Mt	Midway- Thurlow, 8-15%	Poor-Fair	Fair	Fair	Poor	Poor	Good	Severe	Severe	Severe	Moderate	Severe
Mw	Midway- Elso, Rocky 35-75%	Poor	Poor	Poor	Poor	Poor	Good	Severe	Severe	Severe	Severe	Severe
Rc	Rapelje, 2-8%	Fair	Fair	Fair	Poor	Poor	Good	Moderate	Moderate	Moderate	Slight	Severe
Rh	Relan-Cabba 4-8%	Fair	Fair	Fair	Poor	Poor	Good	Severe	Moderate	Moderate	Moderate	Severe
Rk	Relan- Gravelly, 4-8%	Fair	Fair	Good	Poor	Fair	Good	Severe	Moderate	Moderate	Moderate	Moderate
Ro	Remmit-Ocean Lake, 8-25%	Poor-Fair	Poor-Fair	Poor	Poor	Poor	Good	Severe	Moderate	Moderate- Severe	Moderate- Severe	Moderate- Severe
Rs	Ringling, Slaty, 20-50%	Poor	Poor	Poor	Fair	Good	Good	Severe	Moderate	Severe	Severe	Severe
Ru	Ringling- Relan, 6-25%	Poor-Fair	Poor-Fair	Poor	Fair	Good	Good	Severe	Moderate	Moderate- Severe	Moderate- Severe	Moderate- Severe
Rt	Ringling- Cabba, 15-50%	Poor	Poor	Poor	Poor	Fair	Good	Severe	Moderate	Severe	Severe	Severe
Tm	Thurlow, 2-4%	Fair-Good	Good	Good	Poor	Poor	Good	Slight	Moderate	Moderate	Moderate	Severe
To	Thurlow, 4-8%	Fair-Good	Fair-Good	Good	Poor	Poor	Good	Slight	Moderate	Moderate	Moderate	Severe
Tr	Thurlow, 8-15%	Fair	Poor-Fair	Good	Poor	Poor	Good	Moderate	Moderate	Moderate	Moderate	Severe
Vo	Vananda Clay, 2-4%	Poor	Poor	Poor	Poor	Poor	Good	Slight	Severe	Severe	Severe	Severe
Vr	Vona- Remmit, 4-8%	Fair	Fair	Fair	Poor	Poor	Good	Moderate	Moderate	Slight- Moderate	Slight	Severe

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Table 62  
Sheet 1 of 2

PUMPKIN CREEK  
ENGINEERING PROPERTIES OF SOILS  
MEASUREMENTS AND INTERPRETATIONS

Map Symbol (SCS) (1)	Soil Name (2)	Depth From Surface of Typical Profile (inches) (3)	Depth To		Hydrological Soil Group (6)	Shrink - Swell Potential (7)	Corrosivity		Classification			Coarse Fraction (13)
			Hard Bedrock (4)	Seasonal High Water Table (inches) (5)			Uncoated Steel (8)	Concrete (9)	USDA Text. (10)	Unified (11)	AASHTO (12)	
Ab	Arvada-Bone 0-4%	0-17	>60	None	D	High	High	Mod.	C-SiC	CH	A-7	None
Be	Bew 2-4%	0-60	>60	None	D	High	High	Low	SiC-C	CH	A-7	None
Bw	Bew 4-8%	0-60	>60	None	D	High	High	Low	SiC-C	CH	A-7	None
Ce	Cushman- Elsa 4-8%	0-26	20-40	None	C	Low	Mod-High	Low	L-CL	CL	A-6	None
Ch	Cushman- Elsa 8-15%	20-26	20-40	None	C	Low-Mod.	Mod-High	Low	SiL-CL	CL-ML	A-4 A-6	None
Ec	Elsa SiL 8-15%	0-20	<20	None	C	Low	Mod-High	Low	SiL	ML	A-4	None
El	Elsa SiL 15-45%	0-20	<20	None	C	Low	Mod-High	Low	SiL	ML	A-4	None
Fd	Farland SiL 2-4%	0-72	>60	None	C	Low-Mod	Low	Low	SiL-SiCL	ML	A-4	None
Fr	Fort Collins 2-4%	0-60	>70	None	C	Mod	Mod.	Low-Mod.	SiL-SiCL	CL	A-6	None
Ca	Calata 4-8%	0-42	>40	None	D	High	High	Low-Mod.	SiC-C	CH	A-7	None
Hc	Haverson	0-60	>60	None	C	Low-Mod	High	Low-Mod.	L-SiCL	ML-CL	A-4 A-6	None
Hk	Heldt 2-4%	0-44	>60	None	C	Mod	Mod-High	Low	SiCL	CL	A-6	None
Hn	Hesper 0-2%	0-60	>60	None	C	Mod	Mod.	Low	SiL-SiCL	CL	A-6	None
Ho	Hesper 2-4%	0-60	>60	None	C	Mod	Mod.	Low	SiL-SiCL	CL	A-6	None
Hp	Hesper 4-8%	0-60	>60	None	C	Mod	Mod.	Low	SiL-SiCL	CL	A-6	None
Hr	Hesper 8-15%	0-60	>60	None	C	Mod	Mod.	Low	SiL-SiCL	CL	A-6	None
Hs	Hopley- Relan 4-8%	26-60	42-60	None	C	Low	Low	Low	L-SiL	ML	A-4	5-10
Ht	Hydro 0-2%	0-42	>60	None	C	Mod-High	High	Mod	SiCL	CL	A-6	None
Hu	Hydro 2-4%	0-42	>60	None	C	Mod-High	High	Mod	SiCL	CL	A-6	None
Hw	Hydro- Arvada 2-8%	17-42	>60	None	D	High	High	Mod	SiCL-C	CH	A-7	None
Hx	Hydro-Elsa 8-15%	0-20	20-60	None	C	Low-Mod	Mod-High	Low-Mod	SiL-SiCL	CL-ML	A4-A6	None

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Table 62  
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PUMPKIN CREEK  
ENGINEERING PROPERTIES OF SOILS  
MEASUREMENTS AND INTERPRETATIONS

Map Symbol (SCS) (1)	Soil Name (2)	Depth From Surface of Typical Profile (inches) (3)	Depth To		Hydrological Soil Group (6)	Shrink- Swell Potential (7)	Corrosivity		Classification			Coarse Fraction (13)
			Hard Bedrock (4)	Seasonal High Water Table (inches) (5)			Uncoated Steel (8)	Concrete (9)	USDA Text. (10)	Unified (11)	AASHTO (12)	
Hy	Hydro- F. Collins 0-2%	42-60	>60	None	C	Mod.	Mod-High	Low-Mod.	SiL-SiCL	CL	A-6	None
Mc	McRae 1-2%	0-65	>60	None	C	Low	Mod-High	Low-Mod.	SiL-CL	ML	A-4	None
Md	McRae 2-4%	0-65	>60	None	C	Low	Mod-High	Low-Mod.	SiL-CL	ML	A-4	None
Mf	Midway 2-8%	0-7	<20	None	C	High	High	Low-Mod.	CL	CL	A-6	None
Mg	Midway- Elso 8-35%	7-20	<20	None	C	Low-High	Mod-High	Low-Mod.	SiL-CL	ML-CL	A4-A6	None
Mr	Midway- Rockland 15-35%	0-7	<20	None	C	High	High	Mod.	CL	CL	A-6	None
Mt	Midway- Thurlo 8-15%	7-60	20-60	None	C	Mod-High	High-Mod.	Low-Mod.	SiCL-SiC	CL	A-6	None
Mw	Midway- Elso 35-75%	7-20	<20	None	C	Low-High	Mod-High	Low-Mod.	SiL-CL	ML-CL	A4-A6	None
Rc	Rapelje 2-8%	0-26	>60	None	C	Mod.	Mod.	Low	SiCL	CL	A-6	None
Rh	Relan- Cabba 4-8%	16-26	20-60	None	C	Low	Low	Low	L-SiL	ML	A-4	5-10
Rk	Relan- Gravelly 4-8%	0-14	>60	None	B	Low	Low	Low	Gr.L.	GM	A-4	20-40
Ro	Remmit-Ocean Lake 8-25%	15-42	20-60	None	B	Low	Low	Low	FSL	SM	A2-A4	None
Rs	Ringling Slaty 20-25%	0-16	<20	None	B	Low	Low	Low	Slaty L	GM	A-2	55
Ru	Ringling- Relan 6-25%	14-16	20-60	None	B	Low	Low	Low	L-Slaty L	ML-GM	A2-A4	5-55
Rt	Ringling- Cabba 15-50%	20	0-16	None	B-C	Low	Low	Low	GrL-SiL	GM-ML	A2-A4	55
Tm	Thurlo SiCL 2-4%	0-60	>60	None	C	Mod.	Mod.	Low	SiCL-SiC	CL	A-6	None
To	Thurlo SiCL 4-8%	0-60	>60	None	C	Mod.	Mod.	Low	SiCL-SiC	CL	A-6	None
Tr	Thurlo SiCL 8-15%	0-60	>60	None	C	Mod.	Mod.	Low	SiCL-SiC	CL	A-6	None
Vo	Vananda Clay	0-60	>60	None	D	High	High	Mod.	C	CH	A-7	None
Vr	Vona-Remmit FSL 4-8%	42-60	>60	None	B	Low	Low	Low	FSL	SM	A-4	None

SCREENABLE SOIL CHARACTERIZATION  
AS RELATED TO  
LAND RECLAMATION

By  
William B. Peters, Luvern L. Resler, and Robert Vader 1/

Soil is characterized by laboratory methods to confirm judgment in field appraisals. There is a tendency among most laboratory activities to "over test"; i.e., perform too many or unnecessary tests on certain soils at the expense of not performing essential or critical testing on particular samples. Also, laboratory activities tend to emphasize comprehensive analyses of samples from master sites and neglect selection, sequence, and quality control in mass testing performed on a screenable basis. The latter-type testing is frequently handled as routine work utilizing the least dependable personnel and considered not worthy of competent and close supervision. Thus, too often the screenable laboratory testing becomes a liability rather than an asset in supporting land classification surveys. Because the screenable testing represents coverage of areas involving a high sampling density, it serves as an extremely important input into land categorization. Therefore, it should be administered for performance with respect to both quality and quantity commensurate with the goals and objectives of the investigation.

The objective of characterizing soil and overburden will be to support judgment in estimating land reclamation potential. (Overburden refers to the material consolidated or unconsolidated overlying minable resources in relation to surface mining.) Thus, the laboratory analyses must be performed on an action program basis and serve a practical purpose. Therefore, it is essential the physical and chemical characteristics of the soil and overburden be appraised in relation to edaphology; i.e., a medium suitable for the support of plant growth, rather than pedology.

Because the laboratory studies should serve to support field appraisals, all laboratory work should be closely coordinated with fieldwork. For full effectiveness, laboratory studies must be preceded by field studies. The number and type of studies will be determined by area conditions - particularly variability, the controlling project specifications, and needs. There should be a joint plan between field and laboratory investigations prior to taking of samples if maximum utilization of data is

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to be obtained. Problems should be studied rather than standard or routine tests made [Kellogg, 1962].

In submitting soil samples for laboratory characterizations, the laboratory should be furnished with pertinent field appraisals along with the tentative land utilization and quality designation. The soil and subsoil samples should represent genetic horizons with no more than 60-cm depth per sample. Substrata samples should represent uniform overburden with no more than 200 cm per sample unless drill hole diameters preclude obtaining sufficient material for laboratory and greenhouse studies.

The first priority in laboratory characterization should be accomplished by direct and indirect measurements for evaluating soil structure and its stability, soil-cation-exchange capacity or surface area, and soil reaction. After this is accomplished, then consideration should be given to testing that confirms, explains the causes of phenomena previously observed or predicted, reveals the presence of toxic elements (salinity level, boron content, alkali, acidity, reduction products, etc.), and indicates what and how much is required to cope with the soil deficiency under eventual field conditions and the moisture regimen expected to prevail [Peters, 1965].

Based on present knowledge of the area, the support characterizations should include field measurements for water movement and retention in soil and laboratory determinations for structure stability [Gardner, 1945] through measurements of floc volume and hydraulic conductivity of fragmented samples; moisture retentivity at 15-bars pressure; soil reaction by measurement of pH in water and neutral salt solution; soil salinity by measurement of specific electrical conductance of soil-water extracts; soil solution concentration and composition including sodium and calcium plus magnesium; cation exchange capacity; exchangeable cation status; residual gypsum; gypsum requirement; acid soluble carbonates; and others.

Samples collected in a reduced state may be alkaline or neutral while reduced, but acid when oxidized. Therefore, we should be on the "look-out" for such conditions and characteristics and assure reduced material is also analyzed in an aerated condition. Samples exhibiting acidity upon oxidation should be further analyzed to ascertain reduction products associated with the observed phenomenon.

Should conventional acidity; i.e., other than oxidation product, be encountered, the testing will be expanded to include acidity by measurement of neutral salt exchange acidity including aluminum, titratable acidity (amount of acidity neutralized at a selected pH), and soluble aluminum.

In screenable testing, the characterization for moisture retentivity at pressures less than 15 bars is not recommended unless a suitable use can be established. Measurements of moisture retentivity at 15-bars pressure are recommended because water content at this potential is usually correlated with several characteristics including amount and kind of clay, surface area, and cation exchange capacity. Moisture percentages at this potential would probably not be applicable in simulating water content at wilting for native vegetation.

In initial screening, diluted soil-water suspensions may be substituted for the time-consuming, saturated soil extracts in measuring electrical conductance provided limitations are ascertained. The reliability of higher moisture contents even as a tool in screening depends on the kind of salts present. For chloride salts, the results will be only slightly affected by the moisture content, but if sulfate or carbonate salts, which have relatively low solubility, are present in appreciable quantities, the apparent amount of soluble salt will depend on the soil-water ratio [Richards, 1954].

We do not concur in the practice of characterizing vast numbers of samples for textural class through measurements of particle-size distribution. This blanket laboratory analysis for soil textural class is neither required nor desired. Particle-size analysis should be limited to master site characterization, the occasional confirmation of field textural appraisals, and the training of new employees.

In the screenable characterization of samples, a procedure for the sequence of testing and screening of samples should encompass the following phases. Under Phase I of the scheme, all samples would be characterized for (1) soil structure stability through measurement of hydraulic conductivity on a fragmented sample basis during the 6th and 24th hours and volume of wet settled floccules, (2) moisture retentivity at 15-bars pressure, (3) electrical conductivity of soil-water extract, and (4) pH in water and in 0.01 molar calcium chloride solution.

In the second phase, selected samples suspected through the testing results of Phase I to be salt affected should be characterized for electrical conductivity of the saturation extract and sodium adsorption ratio.

In the third phase, selected samples suspected through the testing results of Phases I and II to be salt affected with respect to sodium will be tested for either gypsum requirement or residual gypsum, depending on salinity levels and associated pH values. Residual gypsum will be estimated by measuring calcium plus magnesium in a 1:5 soil-water ratio extract and reported in milliequivalents per 100 grams.

In the fourth phase, selected samples suspected through testing results of Phase I to be highly acid and low in base saturation and nonsaline should be further characterized for bases specifically sodium and calcium plus magnesium and acidity including the aluminum component extractable with a neutral salt; i.e., 1.0N potassium chloride. This will enable computation of effective soil-cation-exchange capacity; i.e., CEC at soil pH and the exchangeable aluminum percentage of this CEC.

In the fifth phase, selected samples having been characterized during Phases I, II, and IV to be saline acid would be characterized for soluble aluminum.

The above-described characterization program would not preclude testing on a "complete analysis" basis on samples from master sites.

## Soils & Water Laboratory Procedures and References

### I. Soil Characterization

#### A. Physical Properties of Soils

1. Disturbed Hydraulic Conductivity is determined by the use of plastic tubes (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 34b:112-113).
2. Settling Volume, Imhoff Cones, (Series 510 Land Classification Techniques and Standards 517.5.7).
3. Particle Size Analyses are determined by pipeting and analysis (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 41:122-123).
4. Particle Density, (C.A. Black, et al., Methods of Soil Analysis Partz, Agronomy No. 9, American Society of Agronomy, 29:371-373), (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 39:122).
5. Bulk Density, (C.A. Black, et al., Methods of Soil Analysis Part 2, Agronomy No. 9, American Society of Agronomy, 30-1:374-390), (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 38:121-122).
6. Moisture Retention in Laboratory is determined by ceramic plates (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 29, 30 and 31:109-110).
7. Field Capacity - field determination.
8. Water holding capacity, determined by calculation, field capacity - wilting point x bulk density x 48 inches = water holding capacity per 48 inches of soil.

#### B. Soluble Cations and Anions

1. Carbonates and bicarbonates are determined with authomated Fisher titralyzer II by acid titration and chlorides are determined with automated Fisher titralyzer II, Specific Ion (Richards, et al., 1954, Diagnosos and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 82:145-146 and 84:146), (C.A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-3.4.1:945-947 and 62-3.5.1:947-948),

- (M.J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, Thirteenth Edition, for carbonate and bicarbonate only 102:52-56), (Bear, et al., Chemical of Soils, 1964), and (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory analysis for chloride only, p. 69).
2. Phosphorus soluble in sodium bicarbonate and Automated Ascorbic Acid (C.A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 73-4.4:1044-1049), (EPA Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600 4-79-020, 365.1:365.1-1-365.1-9).
  3. Nitrate-Nitrite are determined by phenoldisulfonic acid and by Automated cadmium reduction (Richards-et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, Part 2, Agronomy No. 9, American Society of Agronomy 84.5.3:1216-1219) and (M.J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, 1971 Thirteenth Edition, 133:233-237) Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600 4-79-020, 353.2:353.2-1-353.2-7.
  4. Sulfate are determined by Automated Methyl Thymol Blue and turbidimetric, (EPA Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600 4-79-020, 375.2:375.2-1-375.2-4), (M.J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, 1971 Thirteenth Edition, 156C: 334-336).
  5. Sodium, Potassium, Calcium and Mangesium are determined by Automated atomic absorption (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973), and (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods of Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory Analysis, 66, 109, 133 and 143).

C. Trace Metals

1. Trace Metals are determined by atomic absorption with by flame or graphite furnace (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973), (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases", Book 5 - Laboratory Analysis, 50-157) and (M.J. Taras, et al., Standard Methods for the Examination of Water Wasteway, 1971 Thirteen Edition), Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600 4-79-020, DTPA-TEA extraction for Cu, Fe, Mn, and Zn, University of Montana, Missoula, Montana.

D. Chemical Soil Characterization

1. pH reading of 1:5 Soil Suspension (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 21b:102) (C.A. Black, et al., Methods of Soil Analysis, Part 2 Agronomy No. 9, American Society of Agronomy 60-3.4:922-923) and (Bear, et al., Chemical of Soils, 1964).
2. Reading in  $\text{CaCl}_2$  Solution (C.A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 60-3.5:923).
3. Saturation Extract taken from saturation soil paste using Bariod filter press and measuring soluble salts by use of electrode conductivity bridge (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 6, 2 and 3:84-88, 27:107 and 4:89-90), C.A. Black, et al., Methods of Soil Analysis, part 2, Agronomy No. 9, American Society of Agronomy 62-1:933-988) and (Bear, et al., Chemical of Soils, 1964).
4. Exchangeable Sodium and Potassium are extracted' by ammonium acetate solution. Cation-Exchange Capacity determined using Sodium Acetate as index ion and follow with Ammonium Acetate (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 18:100-101 and 19:101) and (C.A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 72-3:1033, 72-3.2.1:1033-1034 and 57-1:891-895).
5. Exchangeable Sodium Percentage is determined by calculation relationship being  $\frac{\text{Na}}{\text{CEC}} \times 100$  (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 20a:101).
6. Gypsum determined by increase in soluble calcium plus magnesium content upon dilution (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 22c:104).
7. Gypsum Requirement (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 22d:104-105).

8. Boron was determined by extraction with hot water (C.A. Black, et al., Methods of Soil Analysis, Part 3 Agronomy No. 9, American Society of Agronomy 75-4:1062-1063 and 62-3.6 949-951).
9. Percent Oranic carbon is determined by Technicon Auto Analyzer II.
10. Total Carbonates express as % calcium carbonate, acid-neutralization, (C.A. Black, et al., Methods of Soil Analysis Part 2, Agronomy No. 9, American Society of Agronomy, 91-4:1387-1388), (Richards et al., 1954 Diagnosis and Improvement of Saline and Alkali Soils USDA Agriculture Handbook No. 60, 23c:105-106).
11. SAR (sodium absorption ratio) determined by calculation  
$$\text{SAR} = \text{Na} / \sqrt{\text{Ca} + \text{Mg}/2}$$

Exhibit 3

Includes the  
following 9 pages

Exhibit 3 - Erosion Evaluations (BLM Form 7310-12) Correlating with USBR  
Point Site Soil Profile Descriptions (see Tables 15 through 23,  
Appendix D)

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF LAND MANAGEMENTPoint Site #5 -  
See Table 15By T. Fiecht1  
Date 11/76

Location

Sec. 8, T. 3 S., R. 49 E.

Treatment affecting the SSF

## DETERMINATION OF EROSION CONDITION CLASS

## SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT*	No visual evidence of movement	Some movement of soil particles	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.	Occurs with each event. Soil and debris deposited against minor obstructions.	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions
	0 1 2 3	4 (5)	6 7 8	9 10 11	12 13 14
SURFACE LITTER*	Accumulating in place	May show slight movement	Moderate movement is apparent, deposited against obstacles	Extreme movement apparent, large and numerous deposits against obstacles	Very little remaining (use care on low productive sites)
	0 1 2 3	4 5 (6)	7 8	9 10 11	12 13 14
SURFACE ROCK*	If present, the distribution of fragments show no movement caused by wind or water	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water	If present, fragments have a poorly developed distribution pattern caused by wind or water	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles	If present, surface rock or fragments are dissected by rills and gullies or are already washed away
	0 1 (2)	3 4 5	6 7 8	9 10 11	12 13 14
PEDESTALS*	No visual evidence of pedestalling	Slight pedestalling, in flow patterns	Small rock and plant pedestals occurring in flow patterns	Rocks and plants on pedestals generally evident, plant roots exposed	Most rocks and plants pedestalled and roots exposed
	0 1 2 3	4 5 (6)	7 8 9	10 11	12 13 14
FLOW PATTERNS*	No visual evidence of flow patterns	Deposition of particles may be in evidence	Well defined, small, and few with intermittent deposits	Flow patterns contain silt and sand deposits and alluvial fans	Flow patterns are numerous and readily noticeable. May have large barren fan deposits.
	0 1 2 3	4 5 (6)	7 8 9	10 11 12	13 14 15
RILLS	No visual evidence of rills	Some rills in evidence at infrequent intervals over 10'	Rills 1/4" to 6" deep occur in exposed places at approximately 10' intervals	Rills 1/2" to 6" deep occur in exposed area at intervals of 5 to 10'	May be present at 3" to 6" deep at intervals less than 5'
	0 1 2 3	4 5 6	(7) 8 9	10 11 12	13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length	Sharply incised gullies cover most of the area and over 50% are actively eroding
	0 1 2 (3)	4 5 6	7 8 9	10 11 12	13 14 15
SITUATION	TOTAL				
	35				

Erosion Condition Classes: Stable 0-20; Slight 21-40; Moderate 41-60; Critical 61-80; Severe 81-100

(Instructions on reverse)

## DETERMINATION OF EROSION CONDITION CLASS

### SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement	Some movement of soil particles	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.	Occurs with each event. Soil and debris deposited against minor obstructions.	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions
SURFACE LITTER *	0 1 2 (3)	4 5	6 7 8	9 10 11	12 13 14
	Accumulating in place	May show slight movement	Moderate movement is apparent, deposited against obstacles	Extreme movement apparent, large and numerous deposits against obstacles	Very little remaining ( <i>use care on low productive sites</i> )
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water	If present, fragments have a poorly developed distribution pattern caused by wind or water	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles	If present, surface rock or fragments are dissected by rills and gullies or are already washed away
PEDESTALS * TALLING *	No visual evidence of pedestalling	Slight pedestalling, in flow patterns	Small rock and plant pedestals occurring in flow patterns	Rocks and plants on pedestals generally evident, plant roots exposed	Most rocks and plants pedestalled and roots exposed
FLOW PATTERNS *	No visual evidence of flow patterns	Deposition of particles may be in evidence	Well defined, small, and few with intermittent deposits	Flow patterns contain silt and sand deposits and alluvial fans	Flow patterns are numerous and readily noticeable. May have large barren fan deposits.
RILLS	No visual evidence of rills	Some rills in evidence at infrequent intervals over 10'	Rills 1/2" to 6" deep occur in exposed places at approximately 10' intervals	Rills 1/2" to 6" deep occur in exposed area at intervals of 5 to 10'	May be present at 3" to 6" deep at intervals less than 5'
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length	Sharply incised gullies cover most of the area and over 50% are actively eroding
SITUATION		TOTAL			
		17			

Erosion Condition Classes: Stable 0-20; Slight 21-40; Moderate 41-60; Critical 61-80; Severe 81-100

(Instructions on reverse)

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF LAND MANAGEMENTPoint Site #1 -  
See Table 17By T. Fiechtl  
Date 11/76Location  
Sec. 20, T. 3 S., R. 49 E.

Treatment affecting the SSF

## DETERMINATION OF EROSION CONDITION CLASS

## SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement				Some movement of soil particles		Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.		Occurs with each event. Soil and debris deposited against minor obstructions.			Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions				
	0	1	2	3	(4)	5	6	7	8	9	10	11	12	13	14	
SURFACE LITTER *	Accumulating in place				May show slight movement		Moderate movement is apparent, deposited against obstacles		Extreme movement apparent, large and numerous deposits against obstacles			Very little remaining ( <i>use care on low productive sites</i> )				
	0	1	2	3	4	(5)	6	7	8	9	10	11	12	13	14	
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water				If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water		If present, fragments have a poorly developed distribution pattern caused by wind or water		If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles			If present, surface rock or fragments are dissected by rills and gullies or are already washed away				
	0	1	(2)		3	4	5	6	7	8	9	10	11	12	13	14
PEDESTALING *	No visual evidence of pedestalling				Slight pedestalling, in flow patterns		Small rock and plant pedestals occurring in flow patterns		Rocks and plants on pedestals generally evident, plant roots exposed			Most rocks and plants pedestalled and roots exposed				
	0	1	2	3	(4)	5	6	7	8	9	10	11	12	13	14	
FLOW PATTERNS *	No visual evidence of flow patterns				Deposition of particles may be in evidence		Well defined, small, and few with intermittent deposits		Flow patterns contain silt and sand deposits and alluvial fans			Flow patterns are numerous and readily noticeable. May have large barren fan deposits.				
	0	1	2	(3)	4	5	6	7	8	9	10	11	12	13	14	15
RILLS	No visual evidence of rills				Some rills in evidence at infrequent intervals over 10'		Rills 1/2" to 6" deep occur in exposed places at approximately 10' intervals		Rills 1/2" to 6" deep occur in exposed area at intervals of 5 to 10'			May be present at 3" to 6" deep at intervals less than 5'				
	0	1	2	(3)	4	5	6	7	8	9	10	11	12	13	14	
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes				A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.		Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.		Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length			Sharply incised gullies cover most of the area and over 50% are actively eroding				
	0	1	2	3	4	5	6	(7)	8	9	10	11	12	13	14	15
SITUATION				TOTAL												
				28												

Erosion Condition Classes: Stable 0-20; Slight 21-40; Moderate 41-60; Critical 61-80; Severe 81-100

(Instructions on reverse)

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF LAND MANAGEMENTPoint Site # 1 -  
See Table 18By  
T. FiechtlDate  
11/76

Location

Sec. 26, T. 3 S., R. 49 E.

Treatment affecting the SSF

## DETERMINATION OF EROSION CONDITION CLASS

## SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement				Some movement of soil particles				Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.				Occurs with each event. Soil and debris deposited against minor obstructions.				Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions			
	0	1	2	(3)	4	5	6	7	8	9	10	11	12	13	14	Very little remaining (use care on low productive sites)				
SURFACE LITTER *	Accumulating in place				May show slight movement				Moderate movement is apparent, deposited against obstacles				Extreme movement apparent, large and numerous deposits against obstacles				If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles			
	0	1	2	(3)	4	5	6	7	8	9	10	11	12	13	14	If present, surface rock or fragments are dissected by rills and gullies or are already washed away				
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water				If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water				Small rock and plant pedestals occurring in flow patterns				Rocks and plants on pedestals generally evident, plant roots exposed				Most rocks and plants pedestalled and roots exposed			
	0	1	2	(3)	4	5	6	7	8	9	10	11	12	13	14	Flow patterns are numerous and readily noticeable. May have large barren fan deposits.				
FLOW PATTERNS *	No visual evidence of flow patterns				Deposition of particles may be in evidence				Well defined, small, and few with intermittent deposits				Flow patterns contain silt and sand deposits and alluvial fans				Flow patterns are numerous and readily noticeable. May have large barren fan deposits.			
	0	1	2	3	(4)	5	6	7	8	9	10	11	12	13	14	15	May be present at 3" to 6" deep at intervals less than 5'			
RILLS	No visual evidence of rills				Some rills in evidence at infrequent intervals over 10'				Rills ½" to 6" deep occur in exposed places at approximately 10' intervals				Rills ¼" to 6" deep occur in exposed area at intervals of 5 to 10'				May be present at 3" to 6" deep at intervals less than 5'			
	0	1	2	(3)	4	5	6	7	8	9	10	11	12	13	14	Sharply incised gullies cover most of the area and over 50% are actively eroding				
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes				A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.				Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.				Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length				Sharply incised gullies cover most of the area and over 50% are actively eroding			
	0	1	2	(3)	4	5	6	7	8	9	10	11	12	13	14	15				
SITUATION				TOTAL																
				21																

Erosion Condition Classes: Stable 0-20; Slight 21-40; Moderate 41-60; Critical 61-80; Severe 81-100

(Instructions on reverse)

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF LAND MANAGEMENTBy T. Fiechtl Date 11/76Point Site #1 -  
See Table 19Location  
Sec. 32, T. 3 S., R. 49 E.

Treatment affecting the SSF

## DETERMINATION OF EROSION CONDITION CLASS

## SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement				Some movement of soil particles	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.				Occurs with each event. Soil and debris deposited against minor obstructions.	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions			
	0	1	2	3	4	(5)	6	7	8		9	10	11	12
SURFACE LITTER *	Accumulating in place				May show slight movement				Moderate movement is apparent, deposited against obstacles	Extreme movement apparent, large and numerous deposits against obstacles	Very little remaining (use care on low productive sites)			
	0	1	2	3	4	(5)	6	7	8		9	10	11	12
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water				If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water				If present, fragments have a poorly developed distribution pattern caused by wind or water	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles	If present, surface rock or fragments are dissected by rills and gullies or are already washed away			
	0	1	2	3	(3)	4	5	6	7	8	9	10	11	12
PEDESTALS *	No visual evidence of pedestalling				Slight pedestalling, in flow patterns				Small rock and plant pedestals occurring in flow patterns	Rocks and plants on pedestals generally evident, plant roots exposed	Most rocks and plants pedestalled and roots exposed			
	0	1	2	3	4	(5)	6	7	8	9	10	11	12	13
FLOW PATTERNS *	No visual evidence of flow patterns				Deposition of particles may be in evidence				Well defined, small, and few with intermittent deposits	Flow patterns contain silt and sand deposits and alluvial fans	Flow patterns are numerous and readily noticeable. May have large barren fan deposits.			
	0	1	2	3	4	(5)	6	7	8	9	10	11	12	13
RILLS	No visual evidence of rills				Some rills in evidence at infrequent intervals over 10'				Rills 1/4" to 6" deep occur in exposed places at approximately 10' intervals	Rills 1/4" to 6" deep occur in exposed area at intervals of 5' to 10'	May be present at 3" to 6" deep at intervals less than 5'			
	0	1	2	(3)	4	5	6	7	8	9	10	11	12	13
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes				A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.				Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length	Sharply incised gullies cover most of the area and over 50% are actively eroding			
	0	1	2	3	4	5	6	7	(8)	9	10	11	12	13
SITUATION					TOTAL									
					34									

Erosion Condition Classes: Stable 0-20; Slight 21-40; Moderate 41-60; Critical 61-80; Severe 81-100

(Instructions on reverse)

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF LAND MANAGEMENTPoint Site #1 -  
See Table 20By  
T. FiechtlDate  
11/76

## DETERMINATION OF EROSION CONDITION CLASS

## SOIL SURFACE FACTORS (SSF)

Treatment affecting the SSF									
Location Sec. 28, T. 3 S., R. 49 E.									
SOIL MOVEMENT *	No visual evidence of movement			Some movement of soil particles			Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.		
	0	1	2	(3)	4	5	6	7	8
SURFACE LITTER *	Accumulating in place			May show slight movement			Moderate movement is apparent, deposited against obstacles		
	0	1	2	(3)	4	5	6	7	8
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water			If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water			If present, fragments have a poorly developed distribution pattern caused by wind or water		
	0	1	(2)	3	4	5	6	7	8
PEDESTALING *	No visual evidence of pedestalling			Slight pedestalling, in flow patterns			Small rock and plant pedestals occurring in flow patterns		
	0	1	2	(3)	4	5	6	7	8
FLOW PATTERNS *	No visual evidence of flow patterns			Deposition of particles may be in evidence			Well defined, small, and few with intermittent deposits		
	0	1	2	3	4	(5)	6	7	8
RILLS	No visual evidence of rills			Some rills in evidence at infrequent intervals over 10'			Rills 1/2" to 6" deep occur in exposed places at approximately 10' intervals		
	0	1	2	(3)	4	5	6	7	8
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes			A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.			Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.		
	0	1	2	3	(4)	5	6	7	8
SITUATION				TOTAL					
				23					

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF LAND MANAGEMENTPoint Site #13 -  
See Table 21

By T. Fiechtl

Date  
11/76Location  
Sec. 34, T. 2 S., R. 49 E.

## DETERMINATION OF EROSION CONDITION CLASS

## SOIL SURFACE FACTORS (SSF)

Treatment affecting the SSF

SOIL MOVEMENT *	No visual evidence of movement			Some movement of soil particles			Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.			Occurs with each event. Soil and debris deposited against minor obstructions.			Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions		
	0	1	2	③	4	5	6	7	8	9	10	11	12	13	14
SURFACE LITTER *	Accumulating in place			May show slight movement			Moderate movement is apparent, deposited against obstacles			Extreme movement apparent, large and numerous deposits against obstacles			Very little remaining ( <i>use care on low productive sites</i> )		
	0	1	2	③	4	5	6	7	8	9	10	11	12	13	14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water			If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water			If present, fragments have a poorly developed distribution pattern caused by wind or water			If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles			If present, surface rock or fragments are dissected by rills and gullies or are already washed away		
	0	1	②	3	4	5	6	7	8	9	10	11	12	13	14
PEDESTALING *	No visual evidence of pedestalling			Slight pedestalling, in flow patterns			Small rock and plant pedestals occurring in flow patterns			Rocks and plants on pedestals generally evident, plant roots exposed			Most rocks and plants pedestalled and roots exposed		
	0	1	2	③	4	5	6	7	8	9	10	11	12	13	14
FLOW PATTERNS *	No visual evidence of flow patterns			Deposition of particles may be in evidence			Well defined, small, and few with intermittent deposits			Flow patterns contain silt and sand deposits and alluvial fans			Flow patterns are numerous and readily noticeable. May have large barren fan deposits.		
	0	1	2	③	4	5	6	7	8	9	10	11	12	13	14
RILLS	No visual evidence of rills			Some rills in evidence at infrequent intervals over 10'			Rills ½" to 6" deep occur in exposed places at approximately 10' intervals			Rills ¾" to 6" deep occur in exposed area at intervals of 5 to 10'			May be present at 3" to 6" deep at intervals less than 5'		
	0	1	2	③	4	5	6	7	8	9	10	11	12	13	14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes			A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.			Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.			Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length			Sharply incised gullies cover most of the area and over 50% are actively eroding		
	0	1	2	3	4	5	⑥	7	8	9	10	11	12	13	14
15															

SITUATION

TOTAL

23

Erosion Condition Classes: Stable 0-20; Slight 21-40; Moderate 41-60; Critical 61-80; Severe 81-100

(Instructions on reverse)

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF LAND MANAGEMENTPoint Site #1 -  
See Table 22

By T. Fiechtl

Date 11/76

Location

Sec. 14, T. 3 S., R. 49 E.

Treatment affecting the SSF

## DETERMINATION OF EROSION CONDITION CLASS

SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	Some movement of soil particles				Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.				Occurs with each event. Soil and debris deposited against minor obstructions.				Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions			
	0	1	2	(3)	4	5	6	7	8	9	10	11	12	13	14	
SURFACE LITTER *	Accumulating in place				May show slight movement				Moderate movement is apparent, deposited against obstacles				Extreme movement apparent, large and numerous deposits against obstacles			
	0	1	2	(3)	4	5	6	7	8	9	10	11	12	13	14	
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water				If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water				If present, fragments have a poorly developed distribution pattern caused by wind or water				If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles			
	0	1	(2)		3	4	5	6	7	8	9	10	11	12	13	14
PEDESTALING *	No visual evidence of pedestalling				Slight pedestalling, in flow patterns				Small rock and plant pedestals occurring in flow patterns				Rocks and plants on pedestals generally evident, plant roots exposed			
	0	1	2	(3)	4	5	6	7	8	9	10	11	12	13	14	
FLOW PATTERNS *	No visual evidence of flow patterns				Deposition of particles may be in evidence				Well defined, small, and few with intermittent deposits				Flow patterns contain silt and sand deposits and alluvial fans			
	0	1	2	(3)	4	5	6	7	8	9	10	11	12	13	14	15
RILLS	No visual evidence of rills				Some rills in evidence at infrequent intervals over 10'				Rills 1/4" to 6" deep occur in exposed places at approximately 10' intervals				Rills 1/4" to 6" deep occur in exposed area at intervals of 5 to 10'			
	0	1	2	(3)	4	5	6	7	8	9	10	11	12	13	14	
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes				A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.				Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.				Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length			
	0	1	2	(3)	4	5	6	7	8	9	10	11	12	13	14	15
SITUATION				TOTAL												
				20												

Erosion Condition Classes: Stable 0-20; Slight 21-40; Moderate 41-60; Critical 61-80; Severe 81-100

(Instructions on reverse)

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF LAND MANAGEMENTPoint Site #1 -  
See Table 23By  
T. FiechtlDate  
11/76

Location

Sec. 18, T. 3 S., R. 49 E.

Treatment affecting the SSF

## DETERMINATION OF EROSION CONDITION CLASS

## SOIL SURFACE FACTORS (SSF)

SOIL SURFACE FACTORS	No visual evidence of movement				Some movement of soil particles				Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.				Occurs with each event. Soil and debris deposited against minor obstructions.				Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions			
	0	1	2	③	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
SURFACE LITTER*	Accumulating in place				May show slight movement				Moderate movement is apparent, deposited against obstacles				Extreme movement apparent, large and numerous deposits against obstacles				Very little remaining (use care on low productive sites)			
	0	1	2	③	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
SURFACE ROCK*	If present, the distribution of fragments show no movement caused by wind or water				If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water				If present, fragments have a poorly developed distribution pattern caused by wind or water				If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles				If present, surface rock or fragments are dissected by rills and gullies or are already washed away			
	0	1	2	②	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
PEDESTALS*	No visual evidence of pedestalling				Slight pedestalling, in flow patterns				Small rock and plant pedestals occurring in flow patterns				Rocks and plants on pedestals generally evident, plant roots exposed				Most rocks and plants pedestalled and roots exposed			
	0	1	2	③	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FLOW PATTERNS*	No visual evidence of flow patterns				Deposition of particles may be in evidence				Well defined, small, and few with intermittent deposits				Flow patterns contain silt and sand deposits and alluvial fans				Flow patterns are numerous and readily noticeable. May have large barren fan deposits.			
	0	1	2	③	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
RILLS	No visual evidence of rills				Some rills in evidence at infrequent intervals over 10'				Rills 1/2" to 6" deep occur in exposed places at approximately 10' intervals				Rills 1/2" to 6" deep occur in exposed area at intervals of 5' to 10'				May be present at 3" to 6" deep at intervals less than 5'			
	0	1	2	③	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes				A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.				Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.				Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length				Sharply incised gullies cover most of the area and over 50% are actively eroding			
	0	1	2	③	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
SITUATION				TOTAL																
				20																

Erosion Condition Classes: Stable 0-20; Slight 21-40; Moderate 41-60; Critical 61-80; Severe 81-100

(Instructions on reverse)

## GLOSSARY

- Alluvium - A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material deposited by a stream or other body of running water as a sorted or semisorted sediment in the bed of the stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.
- Annual Plant (annuals) - A plant that completes its life cycle and dies in 1 year or less.
- Aspect - The direction toward which a slope faces. Exposure.
- Available Nutrient - The part of the supply of a plant nutrient in the soil that can be taken up by plants at rates and in amounts significant to plant growth.
- Available Water - The part of the water in the soil that can be taken up by plants at rates significant to their growth. Usable: obtainable.
- Bedrock - Any consolidated material (shale, sandstone, etc.) soft, weathered or hard that has remained in place and is relatively unchanged.
- Broadcast Seeding - Scattering seed on the surface of the soil. Contrast with drill seeding which places the seed in rows in the soil.
- Buffer - Substances in soil or water that act chemically to resist changes in reaction or pH.
- Calcareous Soil - Soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1 normal hydrochloric acid.
- Capillary Water - The water held in the "capillary" or small pores of a soil, usually with tension greater than 60 centimeters of the water. Much of this water is considered to be readily available to plants.
- CFS, Cubic feet per second - measurement of water flow.
- Channel Stabilization - Erosion prevention and stabilization of velocity distribution in a channel, using jetties, drops, revetments, vegetation, and other measures.
- Clay (soils) - (1) A mineral soil separate consisting of particles less than 0.002 millimeter diameter. (2) A soil textural class. (3) (engineering) A fine-grained soil that has a high plasticity index in relation to the liquid limits.
- Colluvium - A general term applied to loose, heterogeneous (mixed) deposits of soil material and/or rock fragments near the base of rather steep slopes. The deposits have accumulated through mass wasting (slides), soil creep, and local wash.

Compaction - The closing of the pore spaces among the particles of soil and rock, generally caused by running heavy equipment over the area, as in the process of leveling the overburden material of strip mine banks.

Companion Crop - (See Nurse Crop).

Conifer - A tree belonging to the order Coniferae, usually evergreen with cones and needle-shaped or scale-like leaves and producing wood known commercially as "softwood."

Contour - An imaginary line connecting points of equal height above sea level as they follow the relief of the terrain.

Cool-Season Plant - A plant that makes its major growth during the cool portion of the year, primarily in the spring but in some localities in the winter.

Deciduous - Refers to a tree that sheds all its leaves every year at a certain season.

Deep Chiseling - Deep chiseling is a surface treatment that loosens compacted spoils. The process creates a series of parallel slots on the contour in the spoils surface which impedes water flows and markedly increases infiltration.

Density, Forage - The percent of ground surface which appears to be completely covered by vegetation when viewed directly from above.

Density, Stand - Density of stocking expressed in number of trees per acre.

Dissolved Solids - The difference between the total and suspended solids in water.

Disturbed Land - Land on which excavation has occurred or upon which overburden has been deposited, or both.

Dozer or Bulldozer - Tractor with a steel plate or blade mounted on the front end in such a manner that it can be used to cut into earth or other material and move said material primarily forward by pushing.

Ecology - The science that deals with the mutual relation of plants and animals to one another and to their environment.

Ecosystem - A total organic community in a defined area or time frame.

Effective Precipitation - That portion of total precipitation that becomes available for plant growth. It does not include precipitation lost to deep percolation below the root zone or to surface runoff.

Effluent - Any water flowing out of the ground or from an enclosure to the surface flow network.

**Environment** - All external conditions that may act upon an organism or soil to influence its development, including sunlight, temperature, moisture and other organisms.

**Erodibility** - The relative ease with which one soil erodes under specified conditions of slope as compared with other soils under the same conditions; this applies to both sheet and gully erosion.

**Erosion** - The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Detachment and movement of soil or rock fragments by water, wind or ice, or gravity.

**Essential Element (plant nutrition)** - A chemical element required for the normal growth of plants.

**Evapotranspiration** - A collective term meaning the loss of water to the atmosphere from both evaporation and transpiration by vegetation.

**Excavation** - The act of removing overburden material.

**Fertilizer** - Any natural or manufactured material added to the soil in order to supply one or more plant nutrients.

**Fertilizer Grade** - The guaranteed minimum analysis in whole numbers, in percent, of the major plant nutrient elements contained in a fertilizer material or in a mixed fertilizer. For example, a fertilizer with a grade of 20-10-5 contains 20 percent nitrogen (N), 10 percent available phosphoric acid ( $P_2O_5$ ), and 5 percent water soluble potash ( $K_2O$ ). Minor elements may also be included. Recent trends are to express the percentages in terms of the elemental fertilizer /nitrogen (N), phosphorous (P), and potassium (K)/.

**Fill** - Depth to which material is to be placed (filled) to bring the surface to a predetermined grade. Also, the material itself.

**Forage** - Unharvested plant material which can be used as feed by domestic animals. Forage may be grazed or cut for hay.

**Forest Land** - Land bearing a stand of trees at any age or stature, including seedlings and of species attaining a minimum of 6 feet average height at maturity or land from which such a stand has been removed but on which no other use has been substituted. The term is commonly limited to land not in farms; forests on the farms are commonly called woodland or farm forests.

**Germination** - Sprouting; beginning of growth.

**Gradation** - A term used to describe the series of sizes into which a soil sample can be divided.

**Grain Size** - Physical size of soil particle, usually determined by either sieve or hydrometer analysis.

Ground Cover - Any living or dead vegetative material producing a protective mat on or just above the soil surface.

Ground Water - Subsurface water occupying the saturation zone, from which wells and springs are fed. In a strict sense the term applies only to water below the water table. Also called plerotic water; phreatic water.

Growing Season - Determined by the Lowery-Johnson Method.

Gully Erosion - Removal of soil by running water, with formation of deep channels that cannot be smoothed out completely by normal cultivation.

Hydroseeding - Dissemination of seed hydraulically in a water medium. Mulch, lime, and fertilizer can be incorporated into the sprayed mixture.

Impervious - Prohibits fluid flow.

Infiltration - The downward entry of water into the land surface.

Intermittent Stream - A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and is dry for a large part of the year.

Land Classification - Classification of specific bodies of land according to their characteristics or to their capabilities for use. A use capability classification may be defined as one based on both physical and economic considerations according to their capabilities for man's use, with sufficient detail of categorical definition and cartographic (mapping) expression to indicate those differences significant to men.

Land Use Planning - The development of plans for the uses of land that, over long periods, will best serve the general welfare, together with the formulation of ways and means for achieving such uses.

Leaching - The removal of materials in solution by the passage of water through soil.

Leachate - Liquid that has percolated through a medium and has extracted dissolved or suspended materials from it.

Legume - A member of the legume or pulse family, leguminosae. One of the most important and widely distributed plant families. Includes many valuable food and forage species, such as the peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches and kudzu. Practically all legumes are nitrogen-fixing plants.

Lime - From the strictly chemical standpoint, refers to only one compound, calcium oxide (CaO); however, the term lime is commonly used in agriculture to include a great variety of materials which are usually composed of the oxide, hydroxide, or carbonate of calcium or of calcium and magnesium. The most commonly used forms of agricultural

line are ground limestone, marl, and oyster shells (carbonates), hydrated lime (hydroxides), and burnt lime (oxides).

Quicklime - limestone + heat (calcined)  $\text{CaO}$

Hydrated Lime - quicklime +  $\text{H}_2\text{O}$   $\text{Ca(OH)}_2$

Slaked lime - same as hydrated but slaking equipment is used for adding water

Milk of lime - water mixture containing lime in solution + lime in suspension

Micro-Climate - A local climatic condition near the ground resulting from modification of relief, exposure, or cover.

Micro-Nutrients - Nutrients in only small, trace, or minute amounts.

Mined-Land - Land with new surface characteristics due to the removal of mineable commodity by surface mining methods and subsequent surface reclamation.

Mulch - A natural or artificial layer of plant residue or other materials placed on the soil surface to protect seeds, to prevent blowing, to retain soil moisture, to curtail erosion, and to modify soil temperature.

Natural Revegetation - Natural reestablishment of plants; propagation of new plants over an area by natural processes.

Natural seeding (Volunteer) - Natural distribution of seed over an area.

Neutralization - The process of adding an acid or alkaline material to water or soil to adjust its pH to a neutral position.

Neutral Soil - A soil in which the surface layer, at least from normal plow depth, is neither acid nor alkaline in reaction. For most practical purposes, soil with a pH ranging from 6.6 through 7.3.

Nitrogen Fixation - The conversion of atmospheric (free) nitrogen to nitrogen compounds. In soils the assimilation of free nitrogen from the air by soil organisms (making the nitrogen eventually available to plants). Nitrogen fixing organisms associated with plants such as the legumes are called symbiotic; those not definitely associated with plants are called nonsymbiotic.

Nurse Crop - A planting or seeding that is used to protect a tender species during its early life. A nurse crop is usually temporary and gives way to the permanent crop. Sometimes referred to as a companion crop.

Nutrients - Any element taken into a plant that is essential to its growth.

Overburden - All unconsolidated (soil, till, outwash, alluvium, etc.) and consolidated (shale, sandstone, etc.) materials which lie above the coal.

Percolation - Downward movement of water through soils.

Permeability - The measure of the capacity for transmitting a fluid through the substance. In this report the substance is overburden (soil and bedrock).

pH - The symbol or term refers to a scale commonly used to express the degrees of acidity or alkalinity. On this scale pH of 1 is the strongest acid, pH of 14 is the strongest alkali, pH of 7 is the point of neutrality at which there is neither acidity or alkalinity. pH is not a measure of the weight of acid or alkali contained in or available in a given volume (-Log of  $H^+$  activity).

Pollution - Environmental degradation resulting from man's activities or natural events.

Pond - A body of water of limited size either naturally or artificially confined and usually smaller than a lake.

Rain - (1) Heavy--Rain which is falling at the time of observation with an intensity in excess of 0.30 in. per hr (over 0.03 inch in 6 min).  
(2) Light--Rain which is falling at the time of observation with an intensity of between a trace and 0.10 in. per hr (0.01 inch in 6 min).  
(3) Moderate--Rain which is falling at the time of observation with an intensity of between 0.11 in. per hr (0.01+ inch in 6 min) and 0.30 in. per hr (0.03 inch in 6 min).

Range Land - The natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs.

Percolation Rate - Usually expressed as a velocity, at which water moves through saturated granular material. The term is also applied to quantity per unit or time of such movement, and has been used erroneously to designate infiltration rate or infiltration capacity.

Reclamation - The process of reconverting mined land to its former or other productive uses.

Reconstructed Profile - The result of selective placement of suitable overburden material on reshaped spoils.

Recreation Land - Land and water used, or usable primarily as sites for outdoor recreation facilities and activities.

Reforestation - The natural or artificial restocking of an area with forest trees.

Regrading - The movement of earth over a depression to change the shape of the land surface. A finer form of backfilling.

Rehabilitation - Implies that the land will be returned to a form and productivity in conformity with a prior land use plan, including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values.

Revegetation - The reestablishment of a vegetative cover following land disturbance.

Ripping - The act of breaking, with a tractor-drawn ripper or long angled steel tooth, compacted soils or rock into pieces small enough to be economically excavated or moved by other equipment as a scraper or dozer.

Runoff - That portion of the rainfall that is not absorbed by the deep strata: is utilized by vegetation or lost by evaporation or may find its way into streams as surface flow.

Saline-Sodic Soil - A soil having a combination of a harmful quantity of salts and either a high degree of sodicity or a high amount of exchangeable sodium, or both, so distributed in the soil profile that the growth of most crop plants is less than normal.

Saline Soil - A soil containing enough soluble salts to impair its productivity for plants but not containing an excess of exchangeable sodium.

Sandstone - A cemented or otherwise compacted detrital sediment composed predominantly of quartz grains, the grades of the latter being those of sand.

Saturation - Completely filled; a condition reached by a material, whether it be in solid, gaseous, or liquid state, which holds another material within itself in a given state in an amount such that no more of such material can be held within it in the same state. The material is then said to be saturated or in a condition of saturation.

Sediment - Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Sediment Basin - A reservoir for the confinement and retention of silt, gravel, rock, or other debris from a sediment-producing area.

Seedbed - The soil prepared by natural or artificial means to promote the germination of seed and growth of seedlings.

Seep - A more or less poorly defined area where water oozes from the earth in small quantities.

Shale - Sedimentary or stratified rock structure generally formed by the consolidation of clay or clay-like material.

Silt - Small mineral soil grains the particles of which range in diameter from 0.05 to 0.002 mm (or 0.02-0.002 mm in the international system).

- Soil (See Acid Soil and Alkaline Soil) - Surface layer of the earth, ranging in thickness from a few inches to several feet composed to finely divided rock debris mixed with decomposing vegetative and animal matter which is capable of supporting plant growth.
- Soil Amendment - Any substance used to alter one or more of the many soil properties. These include soil conditioning agents, fertilizers, lime and manures, to name a few.
- Soil Conserving Crops - Crops that prevent or retard erosion and maintain or replenish rather than deplete soil organic matter.
- Soil Porosity - The degree to which the soil mass is permeated with pores or cavities. It is expressed as the percentage of the whole volume of the soil which is unoccupied by solid particles.
- Soil Profile - A vertical section of the soil through all its horizons and extending into the parent material.
- Soil Structure - The combination or arrangement of primary soil particles into secondary particles, units, or peds.
- Solum - The upper part of a soil profile, above the parent material, in which the processes of soil formation are active. The solum in mature soils includes the A and B horizons. Usually the characteristics of the material in these horizons are quite unlike those of the underlying parent material. The living roots and other plant life and animal life characteristic of the soil are largely confined to the solum.
- Spoil - The overburden or non-coal material removed in gaining access to the coal or mineral material in surface mining.
- Spoil Bank (Spoil Pile) - Area created by the deposited spoil or overburden material prior to backfilling. Also called cast overburden.
- Stratified - Composed of, or arranged in, strata or layers, as stratified alluvium. The term is applied to geological materials. Those layers in soils that are produced by the processes of soil formation are called horizons, while those inherited from parent material are called strata.
- Strip - To mine a deposit by first taking off the overlying burden.
- Stripping - The removal of earth or non-ore rock materials as required to gain access to the ore or mineral materials wanted. The process of removing overburden or waste material in a surface mining operation.
- Subsoil - The B horizon of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil) in which roots normally grow. Although a common term, it cannot be defined accurately. It has been carried over from early days when "soil" was conceived only as the plowed soil and that under it as "subsoil."

Substratum - Alluvial, colluvial, or bedrock material that underlies the soil profile.

Surface Mining - Refers to a procedure of mining which entails the complete removal of all material from over the resource to be mined in a series of rows or strips; also referred to as "strip mining."

Surface Soil - The upper part of arable soils commonly stirred by tillage implements or an equivalent depth (5 to 8 inches) in non-arable soils.

Suspended Solids - Sediment which is in suspension in water but which will physically settle out under quiescent conditions (as differentiated from dissolved material).

Terrace - Sloping ground cut into a succession of benches and steep inclines for purposes of cultivation or to control surface runoff and minimize soil erosion.

Terraced Slope - A slope that is intersected by one or more terraces.

Texture (Soils) - Refers to the fineness or coarseness of a soil. Specifically, it refers to the relative proportions of the various soil separates (sand, silt, clay) in a given soil.

Topdressing Material - Material that is well suited for plant media. Desired characteristics include: fertile, good tilth, permeable, contains organic matter, nonsaline, nonsodic and has water stable aggregates.

Tilth - The physical condition of a soil in respect to its fitness for the growth of a specified plant.

Topography - The shape of the ground surface, such as hills, mountains, or plains. Steep topography indicates steep slopes or hilly land; flat topography indicates flat land with minor undulations and gentle slopes.

Toxic Spoil (See also Acid Spoil) - Includes acid spoil with pH below 4.0. Also refers to spoil containing excessive levels of exchangeable sodium or trace elements (i.e., selenium, lead, etc.).

Transpiration - The normal loss of water vapor to the atmosphere from plants.

Unconsolidated (soil material) - Soil material in a form of loose aggregation.

Vegetation - General term including grasses, legumes, shrubs, trees naturally occurring and planted intentionally.

Vegetative Cover - The entire vegetative canopy on an area.

Volunteer - Springing up spontaneously or without being planted; a volunteer plant.

Weathering - The group of processes, such as chemical action of air and rainwater and of plants and bacteria and the mechanical action of changes in temperature, whereby rocks, on exposure to the weather, change in character, decay, and finally crumble.

Wildlife - Undomesticated vertebrate animals, except fish, considered collectively.

APPENDIX E  
GREENHOUSE



SOIL ANALYSES VS. RELATIVE YIELDS OF WESTERN WHEATGRASS

SOIL TEST DATA

Relative Yield  
%

Sample Number	Depth (ft.)	Western Wheat	Available P (ppm) Post Plant	Zn	Fe	Cu	Mn	K	pH 1:1	SAR 1:1	Elect. Cond. 1:1
Garr Al	Surface	100									
T2117	0.0-1.5	114	3	.94	10.8	1.12	8.3	192	8.0	1.1	1.0
T2112	1.0-2.5	104	1	1.2	10.8	1.4	5.4	170	8.1	.2	.6
T2114	4.0-6.0	100	30	1.0	10.0	1.4	4.6	180	8.6	4.1	1.3
T2132	2.5-4.0	99	3	.9	8.3	1.7	6.8	182	8.7	1.7	.9
T2111	0.0-1.0	98	2	1.5	14.0	1.56	13.0	200	7.5	.2	.7
T2080	1.0-2.5	91	2	1.27	4.05	.94	5.1	42	8.0	.3	.5
T2134	5.5-7.0	91	4	.5	---	1.8	5.2	268	8.3	---	6.5
T2136	8.5-10.0	89	3	.6	7.0	1.3	4.0	216	8.3	---	2.7
T2090	8.5-10.0	86	3	.5	7.1	1.1	3.0	92	8.4	4.3	8.7
T2086	1.5-3.0	84	4	.9	13.0	1.9	4.8	200	8.3	5.1	3.5
T2091	0.0-1.0	84	5	.64	8.8	2.1	5.2	360	8.1	.3	1.4
T2098	0.0-1.0	80	2	.86	10.0	1.37	8.3	160	8.1	1.0	.6
T2123	0.0-1.0	80	5	1.4	---	1.2	10.4	240	8.0	1.1	.9
T2130	0.0-1.0	80	3	.6	14.5	--	16.0	158	7.6	.4	.8
T2079	0.0-1.0	78	2	.70	16.8	1.74	35.0	200	7.5	.3	1.0
T2096	6.5-8.0	77	--	1.5	12.5	2.2	9.9	220	8.1	3.2	6.2
T2092	1.0-3.0	76	22	.37	8.4	1.6	5.0	130	8.2	.3	.7
T2115	6.0-8.0	75	2	.8	10.8	1.0	5.6	182	8.2	3.6	6.9
T2133	4.0-5.5	75	4	1.2	15.5	1.9	6.0	292	8.3	---	---
T2113	2.5-4.0	74	35	3.2	11.5	1.6	5.8	152	8.5	.9	.8
T2093	3.0-4.0	71	--	.68	8.0	1.5	7.1	130	8.1	2.2	4.3
T2095	5.0-6.5	71	2	2.0	13.0	2.3	10.3	200	8.2	3.2	6.6
76-101-3	34.5-40.5	71	49	1.8	22.0	.5	2.2	126	8.2	---	2.0
T2094	4.0-5.0	70	7	1.4	9.5	1.8	15.1	200	8.0	4.0	4.6
T2105	0.0-1.5	68	1	.4	8.6	1.5	7.2	172	8.4	8.6	2.9
T2129	8.5-10.0	67	40	3.6	229.7	5.9	.6	194	6.9	6.8	.9
76-101-14	204.0-232.3	67	--	3.88	74.40	3.48	10.2	176	8.5	17.5	1.5
T2118	1.5-3.0	66	3	1.2	10.2	1.2	5.4	174	8.1	5.5	9.8
T2089	7.0-8.5	65	8	.8	27.0	2.6	16.7	260	7.9	6.6	15.0
76-101-13	178.4-204.0	65	43	3.48	60.0	3.92	4.6	220	7.19	22.49	---
76-101-12	154.5-170.8	64	2	3.0	121.2	1.4	16.6	128	8.0	11.3	1.2
T2083	6.0-8.0	63	2	.36	2.7	.76	2.7	22	9.0	2.1	1.1
T2131	1.0-2.5	63	3	.4	9.3	1.3	8.0	134	8.2	.4	1.2

Relative Yield  
%

Sample Number	Depth (ft.)	Western Wheat	Available P (ppm)		Available (ppm)					pH 1:1	SAR 1:1	Elect. Cond. 1:1
			Preplant	Post Plant	Zn	Fe	Cu	Mn	K			
T2097	8.0-10.0	60	5		1.9	11.5	2.4	5.8	200	8.2	4.5	7.3
T2085	0.0-1.5	59	4		4.0	14.0	1.9	16.6	240	8.1	2.2	.9
T2100	2.0-2.5	59	1		.48	12.5	4.9	.8	176	8.4	7.1	.9
T2128	7.5-8.5	59	10	47	2.9	35.8	1.5	2.0	160	7.8	10.7	---
T2088	5.0-7.0	57	8		.7	27.0	2.4	11.6	260	8.0	7.3	11.6
T2116	8.0-10.0	57	3		1.6	10.8	1.1	5.2	170	8.1	2.8	7.2
T2106	1.5-2.5	56	1	26	.4	--	1.2	2.0	118	8.4	14.4	8.5
T2087	3.0-5.0	55	5		.7	11.5	2.2	2.4	220	8.5	7.1	7.7
T2124	1.0-2.5	55	1	24	.7	10.4	1.4	9.8	180	8.3	7.5	1.9
76-101-15	232.3-254.5	55	2		2.84	84.0	1.84	12.4	224	8.15	20.14	---
		T2082	54	1	.54	2.6	.78	2.8	32	8.9	1.38	.8
T2125	3.0-4.0	54	4		.4	7.5	.6	5.2	76	8.6	6.2	4.5
T2135	7.0-8.5	54	4		.7	22.0	1.6	6.0	276	8.3	---	3.4
T2099	1.0-2.0	53	2		1.6	15.8	3.8	.5	178	8.3	10.6	1.8
T2119	3.0-4.5	53	3		1.1	16.0	1.1	5.2	156	8.5	12.7	19.0
T2121	6.0-8.0	52	2		1.2	16.8	1.6	4.8	180	8.1	11.3	6.5
T2122	8.0-10.0	52	3		1.1	---	.74	3.7	170	8.2	14.9	11.5
T2084	8.0-10.0	51	1		.24	2.3	.48	2.0	20	8.4	2.3	3.5
T2120	4.5-6.0	51	5		1.0	15.6	1.2	4.7	156	8.3	10.2	13.5
T2101	3.5-5.5	50	1		1.0	10.7	1.4	2.2	106	8.5	11.0	1.4
T2127	5.5-7.5	47	1	29	.5	8.5	.6	3.1	36	8.4	7.1	5.0
T2126	4.0-5.5	46	1	32	.5	6.2	.5	2.4	52	8.3	8.4	6.0
T2103	8.0-8.5	44	1		.6	9.8	1.3	5.4	136	8.5	13.8	13.5
T2081	2.5-4.0	41	1		.44	2.4	.6	2.6	24	8.6	.4	.5
76-101-11	142.2-154.5	37	2		3.04	100.0	1.44	31.88	152	7.3	10.1	3.8
T2109	6.0-8.0	36	2	33	2.1	---	2.3	8.8	184	8.9	26.1	10.0
T2102	5.5-8.0	30	2		1.3	9.5	1.6	6.6	162	8.6	15.7	15.0
76-101-1	0.0-12.8	30	8		5.1	32.0	3.6	14.6	272	7.9	---	1.1
T2110	8.0-10.0	29	--	27	1.5	---	2.2	8.6	240	8.8	27.1	---
76-101-4	40.5-57.5	27	3	37	5.3	80.0	4.6	9.6	296	7.5	---	3.2
76-101-2	12.8-34.5	26	3		6.4	37.0	2.8	12.0	300	7.1	---	1.6
T2107	2.5-4.0	24	1	25	.5	8.0	1.2	4.0	156	8.7	19.3	11.8
T2108	4.0-6.0	20	1	32	.6	12.0	1.7	7.0	176	8.8	25.0	13.4
T2104	8.5-10.0	19	2		.4	9.8	.8	6.5	150	8.5	13.7	1.9
76-101-7	103.6-119.1	18	3		4.7	120.0	3.2	17.0	380	7.2	26.8	2.3
76-101-9	126.5-134.0	17	--	32	3.5	59.0	1.9	18.0	200	7.1	17.5	7.2
76-101-10	134.0-141.5	14	3	33	5.2	148.3	2.9	23.3	264	7.4	21.0	3.9
76-101-5	74.4-95.5	11	3		5.7	168.0	3.8	18.8	264	7.0	15.6	11.0

RELATIVE YIELD VS. PLANT ANALYSES DATA

Sample Number	Depth (ft.)	Relative Yield		Plant Analyses Data					
		Western	%	Fe	Zn	Mn	Cu	P	K
		Wheat		ppm	ppm	ppm	ppm	%	%
Control	surface	100		64.6	31.5	39.4	7.3	.57	1.47
T2117	0.0-1.5	114		63.2	16.5	74.5	7.9	.40	1.04
T2112	1.0-2.5	104		64.1	17.9	64.1	7.9	.40	1.28
T2114	4.0-6.0	100							
T2132	2.5-4.0	99		91.5	14.0	108.5	11.5	.45	1.45
T2111	0.0-1.0	98							
T2080	1.0-2.5	91							
T2134	5.5-7.0	91							
T2136	8.5-10.0	89							
T2090	8.5-10.0	86							
T2086	1.5-3.0	84							
T2091	0.0-1.0	84		76.0	19.9	57.4	9.4	.38	1.15
T2098	0.0-1.0	80		58.4	11.9	43.1	13.4	.33	2.0
T2123	0.0-1.0	80							
T2130	0.0-1.0	80							
T2079	0.0-1.0	78		87.4	21.4	84.6	12.3	.43	1.41
T2096	6.5-8.0	77							
T2092	1.0-3.0	76							
T2115	6.0-8.0	75							
T2133	4.0-5.5	75		71.3	15.4	111.9	10.6	.34	2.6
T2113	2.5-4.0	74		91.9	13.7	92.1	10.7	.39	2.4
T2093	3.0-4.0	71		71.5	17.3	78.2	9.4	.5	2.4
T2095	5.0-6.5	71							
76-101-3	34.5-40.5	71		71.8	---	105.3	8.7	.43	1.7
T2094	4.0-5.0	70							
T2105	0.0-1.5	68							
T2129	8.5-10.0	67		69.5	---	82.4	9.7	.40	3.2
76-101-14	104.0-232.3	67							
T2118	1.5-3.0	66							
T2089	7.0-8.5	65		91.2	20.3	180.1	13.7	.38	1.9
76-101-13	178.4-204.0	65		78.0	---	130.4	9.9	.32	3.1
76-101-12	154.5-170.8	64							
T2083	6.0-8.0	63		78.0	16.1	73.1	10.0	.40	1.83
T2131	1.0-2.5	63							

Sample Number	Depth (ft.)	Relative Yield		Plant Analyses Data					
		Western	%	Fe ppm	Zn ppm	Mn ppm	Cu ppm	P %	K %
T2097	8.0-10.0	60							
T2085	0.0-1.5	59							
T2100	2.0-2.5	59							
T2128	7.5-8.5	59							
T2088	5.0-7.0	57		86.4	19.6	183.5	12.1	.40	2.6
T2116	8.0-10.0	57		68.5	27.4	99.7	9.0	.42	3.5
T2106	1.5-2.5	56		76.9	18.5	105.1	11.4	.55	3.4
T2087	3.0-5.0	55							
T2124	1.0-2.5	55							
76-101-15	232.3-254.5	55							
T2082	4.0-6.0	54							
T2125	3.0-4.0	54		75.4	15.3	96.8	8.8	.45	1.6
T2135	7.0-8.5	54							
T2099	1.0-2.0	53							
T2119	3.0-4.5	53		73.6	20.8	95.2	9.5	---	3.17
T2121	6.0-8.0	52							
T2122	8.0-10.0	52							
T2084	8.0-10.0	51		81.4	17.7	57.7	10.9	.47	2.1
T2120	4.5-6.0	51							
T2101	3.5-5.5	50							
T2127	5.5-7.5	47							
T2126	4.0-5.5	46							
T2103	8.0-8.5	44							
T2081	2.5-4.0	41							
76-101-11	142.2-154.5	37		93.7	46.8	121.0	10.2	.46	2.7
T2109	6.0-8.0	36		96.3	33.0	103.2	16.9	.38	2.6
T2102	5.5-8.0	30							
76-101-1	0.0-12.8	30							
T2110	8.0-10.0	29		84.1	22.1	125.0	13.4	.39	2.5
76-101-4	40.5-57.5	27							
76-101-2	12.8-34.5	26		82.5	48.0	137.5	12.5	.31	2.9
T2107	2.5-4.0	24							
T2108	4.0-6.0	20		128.3	21.6	108.1	15.2	.55	2.4
T2104	8.5-10.0	19		89.4	16.7	116.6	9.2	.26	1.8
76-101-7	103.6-119.1	18							
76-101-9	126.5-134.0	17		83.8	40.7	105.2	8.2	.42	2.2
76-101-10	134.0-141.5	14		104.9	53.1	132.7	10.5	.76	3.3
76-101-5	74.4-95.5	11		66.6	42.8	104.7	7.6	.60	2.5

## Soil and Plant Ca, Mg and Na Levels

Sample No.	Soil Data			Plant Analyses			
	NH <sub>4</sub> AC Extractable			Total		Ca %	
	Ca %	Mg %	Na ppm	Western Wheat	Western Wheat	Western Wheat	Western Wheat
T-2079	.4	.03	38	.007	.20	.76	
T-2083	.17	.04	194	.43	.46	.31	
T-2084	.18	.04	220	.14	.43	.37	
T-2088	.44	.22	1240	.06	.31	.23	
T-2089	.75	.18	840	.06	.33	.23	
T-2098	.29	.10	77	.007	.02	.42	
T-2104	.6	.30	2600	.17	.38	.18	
T-2106	.60	.19	2200	.13	.26	.26	
T-2107	.59	.22	3550	.70	.64	.21	
T-2108	.33	.22	3900	.61	.31	.17	
T-2109	.26	.20	3750	.54	.27	.21	
T-2110	.24	.21	3950	.15	.26	.18	
T-2112	.81	.2	50	.007	.31	.37	
T-2113	.74	.2	180	.02	.38	.19	
T-2116	.77	.17	540	.03	.26	.18	
T-2117	.86	.13	220	.009	.25	.45	
T-2119	1.5	.22	3300	---	.27	.20	
T-2091	.52	.07	40	.01	.19	.63	
T-2092	.41	.12	50	---	---	---	
T-2093	.34	.16	320	.05	.35	.58	
T-2124	.90	.14	1460	---	---	---	
T-2125	.8	.08	1120	.09	.23	.25	
T-2126	.2	.06	940	---	---	---	
T-2129	.3	.22	1900	.20	---	---	
T-2132	.78	.21	340	.06	.38	.22	
T-2133	.86	.28	---	.06	.30	.27	
76-101-5	.8	.06	2720	.05	.15	.32	
76-101-9	.3	.05	2050	.06	.17	.31	
76-101-10	.3	.05	2400	.07	.16	.34	
76-101-11	.3	.03	1100	.16	.16	.34	
76-101-13	.26	.05	2500	.08	.17	.33	



## APPENDIX F

### HYDROLOGY



Table 69 -Chemical and spectographic analyses of water samples from  
streams in the vicinity of the Pumpkin Creek study area

STATION NUMBER	STATION NAME	DATE OF SAMPLE	TIME	INSTANTANEOUS DIS- CHARGE (CFS)	SURFACE AREA (SQUARE MILES)	SPE- CIFIC CON- DUCT- ANCE (MICHO- MHOS)	PH (UNITS)
06326050	MIZPAH CREEK AT OLIVE, MT.	75-11-19	1300	.10	129	4700	8.0
	MIZPAH CREEK AT OLIVE, MT.	75-12-11	1000	.22	129	5570	7.5
	MIZPAH CREEK AT OLIVE, MT.	76-01-15	0845	.10	129	4960	7.6
	MIZPAH CREEK AT OLIVE, MT.	76-02-12	1540	.37	129	4730	7.5
	MIZPAH CREEK AT OLIVE, MT.	76-03-11	1300	.30	129	3350	7.5
	MIZPAH CREEK AT OLIVE, MT.	76-04-14	1330	.30	129	3000	8.0
	MIZPAH CREEK AT OLIVE, MT.	76-05-11	1600	.19	129	3380	8.1
	MIZPAH CREEK AT OLIVE, MT.	76-06-09	1025	.05	129	3400	8.1
	MIZPAH CREEK AT OLIVE, MT.	77-01-06	1530	.01	129	5810	7.1
	MIZPAH CREEK AT OLIVE, MT.	77-03-02	1445	.01	129	4720	7.2
	MIZPAH CREEK AT OLIVE, MT.	77-04-06	1410	.65	129	2680	7.9
	MIZPAH CREEK AT OLIVE, MT.	77-05-03	0800	.04	129	3030	7.9
06326200	MIZPAH CREEK NEAR VOLBORG, MT.	75-11-13	1300	.10	510	3300	7.8
	MIZPAH CREEK NEAR VOLBORG, MT.	75-12-09	1600	.10	510	2710	7.7
	MIZPAH CREEK NEAR VOLBORG, MT.	76-01-13	1445	.14	510	2850	7.8
	MIZPAH CREEK NEAR VOLBORG, MT.	76-02-11	1440	4.2	510	1370	7.6
	MIZPAH CREEK NEAR VOLBORG, MT.	76-03-09	1430	1.4	510	2120	7.8
	MIZPAH CREEK NEAR VOLBORG, MT.	76-04-13	1500	.25	510	2740	7.8
	MIZPAH CREEK NEAR VOLBORG, MT.	76-05-10	1930	8.9	510	3120	8.3
	MIZPAH CREEK NEAR VOLBORG, MT.	76-06-08	1745	.45	510	3100	8.0
	MIZPAH CREEK NEAR VOLBORG, MT.	76-07-13	1600	2.3	510	2810	8.1
	MIZPAH CREEK NEAR VOLBORG, MT.	76-08-11	1335	.08	510	2720	7.9
	MIZPAH CREEK NEAR VOLBORG, MT.	76-10-07	1535	.05	510	3500	8.1
	MIZPAH CREEK NEAR VOLBORG, MT.	76-12-02	0900	.02	510	3900	8.2
	MIZPAH CREEK NEAR VOLBORG, MT.	77-01-06	1300	.10	510	3790	7.5
	MIZPAH CREEK NEAR VOLBORG, MT.	77-02-02	1000	.30	510	2940	7.5
	MIZPAH CREEK NEAR VOLBORG, MT.	77-03-01	1200	.05	510	2870	7.6
	MIZPAH CREEK NEAR VOLBORG, MT.	77-04-05	1525	.05	510	3050	8.0
	MIZPAH CREEK NEAR VOLBORG, MT.	77-05-03	1200	.02	510	3900	8.2
06308160	PUMPKIN CREEK NEAR LUESCH, MT.	75-12-10	1600	.30	102	4830	8.0
	PUMPKIN CREEK NEAR LUESCH, MT.	76-01-14	1430	.13	102	5430	7.5
	PUMPKIN CREEK NEAR LUESCH, MT.	76-02-12	1200	.42	102	4600	7.8
	PUMPKIN CREEK NEAR LUESCH, MT.	76-03-11	1000	.31	102	4100	7.9
	PUMPKIN CREEK NEAR LUESCH, MT.	76-04-14	1030	.25	102	5380	8.1
	PUMPKIN CREEK NEAR LUESCH, MT.	76-05-11	1300	.30	102	4900	8.1
	PUMPKIN CREEK NEAR LUESCH, MT.	76-06-09	1300	.05	102	4960	7.8
	PUMPKIN CREEK NEAR LUESCH, MT.	76-07-14	1015	.02	102	5900	7.6
	PUMPKIN CREEK NEAR LUESCH, MT.	77-01-07	0915	.01	102	10000	7.4
	PUMPKIN CREEK NEAR LUESCH, MT.	77-02-02	1545	.01	102	6200	7.6
	PUMPKIN CREEK NEAR LUESCH, MT.	77-03-02	1345	.05	102	6450	7.2
	PUMPKIN CREEK NEAR LUESCH, MT.	77-04-06	1200	1.2	102	4200	8.3
	PUMPKIN CREEK NEAR LUESCH, MT.	77-05-02	1400	.05	102	6300	8.2
06308190	PUMPKIN CREEK NEAR VOLBORG, MT.	75-12-10	1315	.10	386	7000	8.0
	PUMPKIN CREEK NEAR VOLBORG, MT.	76-02-24	1230	1.7	386	3380	8.0
	PUMPKIN CREEK NEAR VOLBORG, MT.	76-03-10	1520	4.6	386	4100	8.1
	PUMPKIN CREEK NEAR VOLBORG, MT.	76-04-15	0930	2.0	386	4850	8.0
	PUMPKIN CREEK NEAR VOLBORG, MT.	76-05-11	1000	3.0	386	5300	8.4
	PUMPKIN CREEK NEAR VOLBORG, MT.	76-06-09	1430	.02	386	5460	8.2
	PUMPKIN CREEK NEAR VOLBORG, MT.	77-03-02	1200	1.0	386	4620	7.1
	PUMPKIN CREEK NEAR VOLBORG, MT.	77-04-06	1545	3.2	386	4200	8.3
	PUMPKIN CREEK NEAR VOLBORG, MT.	77-05-03	1000	.20	386	5900	8.3

Table 69 -Chemical and spectrographic analyses of water samples from streams in the vicinity of the Pumpkin Creek study site--continued

DATE OF SAMPLE	AIR TEMPER- ATURE (DEG C)	TEMPER- ATURE (DEG C)	TUR- BID- ITY (JTU)	DIS- SOLVED OXYGEN (MG/L)	PER- CENT SATUR- ATION	BIO- CHEM- ICAL OXYGEN DEMAND 5 DAY (MG/L)	HARD- NESS (CA, MG) (MG/L)	NON- CAR- BONATE HARD- NESS (MG/L)	DIS- SOLVED CAL- CIUM (CA) (MG/L)	DIS- SOLVED MAG- NE- SIUM (MG) (MG/L)	DIS- SOLVED SODIUM (NA) (MG/L)	PERCENT SODIUM
75-11-19	1.0	2.0	1	13.6	111	.6	2300	1600	320	360	600	36
75-12-11	-2.0	.5	1	1.4	11	1.4	2400	1900	370	360	600	35
76-01-15	.0	.0	3	.0	0	3.4	2200	1600	380	310	510	33
76-02-12	8.0	.0	5	.0	0	2.0	2100	1500	360	290	470	33
76-03-11	-5.5	.0	1	3.2	25	1.2	1500	1100	260	200	320	32
76-04-14	14.0	16.0	2	14.4	164	1.6	1200	910	200	180	280	33
76-05-11	10.0	15.0	2	12.6	140	1.3	1400	1100	210	220	340	34
76-06-09	26.0	22.5	4	9.8	127	6.9	1500	1300	200	250	350	33
77-01-06	.0	.0	5	.0	0	1.4	2100	1200	320	310	390	29
77-03-02	5.0	.5	7	4.6	38	1.8	1800	1400	290	270	400	32
77-04-06	17.0	9.0	3	11.3	111	2.1	1100	840	190	150	220	30
77-05-03	17.5	14.5	2	11.4	124	1.4	1300	1000	170	210	280	32
75-11-13	19.0	4.0	1	9.4	80	.5	680	150	150	73	460	59
75-12-09	6.5	2.0	2	8.5	69	.4	650	150	140	72	420	58
76-01-13	4.0	1.0	3	7.4	56	.4	610	100	130	70	420	59
76-02-11	13.0	1.0	20	6.0	47	6.7	240	40	45	31	200	63
76-03-09	7.0	5.0	10	11.1	97	3.1	420	120	77	55	320	62
76-04-13	24.0	20.0	5	9.6	118	1.3	620	110	130	71	410	59
76-05-10	24.0	19.0	30	6.4	77	2.3	560	150	86	85	530	67
76-06-08	30.5	29.5	10	8.9	131	1.1	600	160	100	84	540	66
76-07-13	23.0	26.5	1	8.1	114	1.9	610	200	100	87	540	65
76-08-11	20.0	25.0	5	8.2	110	1.0	700	250	140	84	430	57
76-10-07	12.0	12.5	10	9.9	103	2.0	700	260	150	79	470	59
76-12-02	.0	2.0	7	7.0	56	1.0	800	200	170	91	510	58
77-01-06	-2.5	1.0	7	4.3	34	2.6	720	160	150	84	480	59
77-02-02	-2.0	.0	7	3.0	23	.8	720	170	150	83	450	57
77-03-01	5.0	.0	6	6.2	47	.9	670	160	130	84	460	60
77-04-05	16.0	12.0	7	9.4	97	1.0	640	140	120	82	470	61
77-05-03	27.5	19.5	4	7.8	92	1.4	740	150	140	95	550	61
75-12-10	.5	.5	7	6.8	53	.4	1600	1000	230	250	630	46
76-01-14	-1.0	.0	5	5.7	29	.7	1800	1200	260	290	760	47
76-02-12	11.0	1.0	5	4.9	39	.4	1500	900	220	220	620	48
76-03-11	-3.0	.5	4	8.2	64	.8	1300	840	190	210	550	47
76-04-14	13.0	14.0	10	4.6	52	2.6	1800	1200	210	300	800	49
76-05-11	8.0	13.0	5	6.4	68	1.2	1600	1000	200	260	690	48
76-06-09	24.5	26.0	5	6.0	85	2.5	1600	1100	170	280	710	49
76-07-14	24.0	22.0	7	6.0	77	4.6	1900	1200	220	340	960	51
77-01-07	1.0	.0	80	.1	1	2.0	2300	1400	310	380	1100	50
77-02-02	.5	.0	45	.0	0	2.0	2100	1400	260	350	880	48
77-03-02	6.5	.0	7	4.3	33	1.1	1400	950	200	220	580	47
77-04-06	19.5	13.0	3	12.4	132	1.3	1300	850	160	200	570	49
77-05-02	24.0	20.5	9	11.8	148	1.4	2000	1300	230	340	900	49
75-12-10	1.0	.0	2	8.3	63	.5	1700	940	230	280	1300	62
76-02-24	15.0	.0	4	8.9	68	2.6	1100	630	150	170	540	52
76-03-10	13.0	.0	3	12.4	95	2.0	1100	650	150	180	630	55
76-04-15	19.0	14.0	3	7.5	81	1.7	1200	710	150	210	770	57
76-05-11	21.0	16.0	9	7.4	83	1.5	1400	840	170	240	840	56
76-06-09	27.0	27.0	10	5.2	115	1.7	1300	870	90	250	880	60
77-03-02	6.0	.0	5	7.2	55	1.8	900	550	130	140	520	55
77-04-06	22.0	12.5	6	10.2	106	1.8	980	590	130	160	610	57
77-05-03	25.0	17.0	3	8.3	95	1.0	1500	970	180	260	900	56

Table 69 -Chemical and spectrographic analyses of water samples from streams in the vicinity of the Pumpkin Creek study area--continued

DATE OF SAMPLE	SODIUM AD- SORP- TION RATIO	DIS- SOLVED PO- TAS- SIUM (K) (MG/L)	BICAR- BONATE (HCO3) (MG/L)	CAR- BONATE (CO3) (MG/L)	ALKA- LINITY AS CACO3 (MG/L)	CARBON DIOXIDE (CO2) (MG/L)	DIS- SOLVED SULFATE (SO4) (MG/L)	DIS- SOLVED CHLO- RIDE (CL) (MG/L)	DIS- SOLVED FLUO- RIDE (F) (MG/L)	DIS- SOLVED SILICA (SiO2) (MG/L)	DIS- SOLVED SOLIDS (SUM OF CONSTI- TUENTS) (MG/L)	DIS- SOLVED SOLIDS (TONS PER AC-FT)
75-11-19	5.5	22	535	0	439	8.6	3200	28	.2	8.2	4800	6.53
75-12-11	5.3	20	658	0	540	33	3000	29	.3	16	4720	6.42
76-01-15	4.7	19	762	0	625	31	2500	3.8	.4	22	4120	5.60
76-02-12	4.5	19	681	0	559	34	2500	26	.3	22	4020	5.47
76-03-11	3.6	11	470	0	386	24	1700	16	.3	15	2750	3.74
76-04-14	3.5	12	406	0	333	6.5	1500	20	.2	.5	2390	3.25
76-05-11	3.9	11	350	0	287	4.4	1900	18	.3	.4	2870	3.90
76-06-09	3.9	11	287	0	235	3.6	1900	17	.2	6.6	2880	3.92
77-01-06	3.7	16	1010	0	828	128	2000	61	.4	39	3640	4.95
77-03-02	4.1	20	559	0	459	56	2200	27	.2	20	3500	4.76
77-04-06	2.9	8.8	310	0	250	6.2	1300	18	.2	7.9	2050	2.79
77-05-03	3.4	8.1	320	0	260	6.4	1600	21	.2	11	2460	3.35
75-11-13	7.7	9.3	637	0	522	16	1100	9.5	.4	16	2130	2.90
75-12-09	7.2	8.8	608	0	499	19	1000	8.9	.3	15	1970	2.68
76-01-13	7.4	9.1	621	0	509	16	1000	7.0	.3	14	1960	2.67
76-02-11	5.6	10	244	0	200	9.8	470	5.8	.2	5.5	888	1.21
76-03-09	6.8	9.2	369	0	303	9.4	820	7.2	.3	7.8	1480	2.01
76-04-13	7.2	9.9	614	0	504	16	1000	8.1	.3	15	1950	2.65
76-05-10	9.7	10	501	0	411	4.0	1300	9.5	.4	6.1	2270	3.09
76-06-08	9.6	10	531	0	436	8.5	1300	9.1	.3	6.5	2310	3.14
76-07-13	9.5	12	502	0	412	6.4	1300	9.8	.4	4.7	2300	3.13
76-08-11	7.1	11	545	0	447	11	1100	8.8	.3	14	2060	2.80
76-10-07	7.7	12	540	0	443	6.9	1200	12	.4	15	2210	3.01
76-12-02	7.9	10	729	0	598	7.4	1300	11	.4	15	2470	3.36
77-01-06	7.8	9.5	683	0	560	35	1100	8.7	.4	18	2190	2.98
77-02-02	7.3	8.0	661	0	542	33	1100	8.4	.4	17	2140	2.91
77-03-01	7.7	8.4	620	0	509	25	1100	8.9	.3	14	2110	2.87
77-04-05	8.1	8.8	605	0	500	9.7	1100	8.6	.3	11	2100	2.86
77-05-03	8.8	9.4	720	0	590	7.3	1300	8.7	.4	14	2470	3.36
75-12-10	6.8	22	716	0	587	11	2200	17	.5	18	3720	5.06
76-01-14	7.7	23	827	0	678	42	3000	14	.6	17	4770	6.49
76-02-12	7.1	20	681	0	559	17	2200	14	.5	14	3650	4.96
76-03-11	6.5	17	613	0	503	12	2000	12	.5	11	3290	4.47
76-04-14	8.3	23	722	0	592	9.2	2700	18	.6	13	4420	6.01
76-05-11	7.6	21	638	0	523	8.1	2400	15	.5	7.8	3910	5.32
76-06-09	7.8	20	597	0	490	15	2700	14	.4	13	4200	5.71
76-07-14	9.5	26	959	0	787	24	3100	14	.6	24	5160	7.02
77-01-07	9.9	23	1110	0	910	71	4000	26	.7	19	6430	8.74
77-02-02	8.4	21	853	0	700	34	3200	21	.6	17	5180	7.04
77-03-02	6.7	18	553	0	454	56	2200	14	.4	12	3520	4.79
77-04-06	7.0	17	510	0	420	4.1	2100	15	.6	9.6	3340	4.54
77-05-02	8.8	24	770	0	630	7.8	3200	20	.7	7.5	5100	6.94
75-12-10	14	21	961	0	788	15	3600	26	.6	13	5950	8.09
76-02-24	7.2	17	544	0	446	8.7	1800	23	.3	9.4	2980	4.05
76-03-10	8.2	15	572	0	469	7.3	2000	12	.4	8.1	3280	4.46
76-04-15	9.5	17	650	0	533	10	2200	14	.4	2.6	3690	5.02
76-05-11	9.7	20	702	0	576	4.5	2600	15	.5	4.7	4240	5.77
76-06-09	11	17	464	0	381	4.7	3100	15	.4	.5	4580	6.23
77-03-02	7.5	19	433	0	355	55	1700	13	.2	11	2750	3.74
77-04-06	8.5	13	480	0	390	3.8	1900	14	.5	8.0	3070	4.18
77-05-03	10	21	670	0	550	5.4	3000	17	.5	4.7	4710	6.41

Table 69 --Chemical and spectrophotographic analyses of water samples from streams in the vicinity of the Pumpkin Creek study area---continued

DATE OF SAMPLE	DIS- SOLVED SOLIDS (TONS PER DAY)	TOTAL NITRITE PLUS NITRATE (N) (MG/L)	TOTAL AMMONIA NITRO- GEN (N) (MG/L)	TOTAL ORGANIC NITRO- GEN (N) (MG/L)	TOTAL KJEL- DAHL NITRO- GEN (N) (MG/L)	TOTAL NITRO- GEN (N) (MG/L)	TOTAL NITRO- GEN (NO3) (MG/L)	TOTAL PHOS- PHORUS (P) (MG/L)	TOTAL ALUM- INUM (AL) (UG/L)	DIS- SOLVED ALUM- INUM (AL) (UG/L)	TOTAL ARSENIC (AS) (UG/L)	DIS- SOLVED ARSENIC (AS) (UG/L)
75-11-19	1.30	.02	.00	1.7	1.7	1.7	7.6	.04	90	0	2	2
75-12-11	2.80	.00	.01	1.3	1.3	1.3	5.8	.03	--	--	--	--
76-01-15	1.11	.02	.13	1.1	1.2	1.2	5.4	.21	80	--	1	--
76-02-12	4.02	.01	1.2	1.8	3.0	3.0	13	.24	--	--	--	--
76-03-11	2.23	.04	.24	1.1	1.3	1.3	5.9	.04	--	--	--	--
76-04-14	1.94	.00	.00	1.0	1.0	1.0	4.4	.04	20	--	1	--
76-05-11	1.47	.03	.04	1.1	1.1	1.1	5.0	.04	--	--	--	--
76-06-09	.39	.02	.09	.91	1.0	1.0	4.5	.05	--	--	--	--
77-01-06	.10	.01	.29	1.3	1.6	1.6	7.1	.30	--	30	--	10
77-03-02	.09	.01	1.5	.70	2.2	2.2	9.8	.09	--	--	--	--
77-04-06	3.60	.05	.00	.55	.55	.60	2.7	.05	--	10	--	0
77-05-03	.27	.01	.05	.47	.52	.53	2.3	.03	--	--	--	--
75-11-13	.58	.01	.02	.29	.31	.32	1.4	.00	60	40	1	1
75-12-09	.53	.00	.02	.31	.33	.33	1.5	.00	--	--	--	--
76-01-13	.74	.02	.04	.09	.13	.15	.66	.00	50	--	0	--
76-02-11	10.1	.03	.00	1.7	1.7	1.7	7.7	.16	--	--	--	--
76-03-09	5.59	.01	.02	1.5	1.5	1.5	6.7	.09	--	--	--	--
76-04-13	1.32	.00	--	--	--	--	--	.02	150	--	1	--
76-05-10	54.5	.01	.02	.90	.92	.93	4.1	.10	--	--	--	--
76-06-08	2.81	.01	.01	.67	.68	.69	3.1	.04	--	--	--	--
76-07-13	14.3	.02	.01	.75	.76	.78	3.5	.07	350	--	3	--
76-08-11	.45	.01	.00	.25	.25	.26	1.2	.01	--	--	--	--
76-10-07	.30	.00	.00	.76	.76	.76	3.4	.03	--	10	--	1
76-12-02	.13	.03	.02	.91	.93	.96	4.3	.05	120	0	0	0
77-01-06	.59	.01	.01	.20	.21	.22	.97	.04	--	0	--	1
77-02-02	1.73	.01	.21	.05	.26	.27	1.2	.01	--	--	--	--
77-03-01	.28	.03	.00	.38	.38	.41	1.8	.02	--	--	--	--
77-04-05	.28	.03	.00	.20	.20	.23	1.0	.02	--	20	--	0
77-05-03	.13	.02	.01	.10	.11	.13	.58	.01	--	--	--	--
75-12-10	3.01	.07	.02	.95	.97	1.0	4.6	.05	--	--	--	--
76-01-14	1.67	.03	.13	1.2	1.3	1.3	5.9	.03	130	--	0	--
76-02-12	4.14	.01	.00	.87	.87	.88	3.9	.02	--	--	--	--
76-03-11	2.75 <sub>3</sub>	.01	.04	.62	.66	.67	3.0	.01	--	--	--	--
76-04-14	2.98	.00	.00	1.5	1.5	1.5	6.6	.07	340	--	3	--
76-05-11	3.17	.02	.03	1.1	1.1	1.1	5.0	.04	--	--	--	--
76-06-09	.57	.13	.03	1.1	1.1	1.2	5.4	.09	--	--	--	--
76-07-14	.28	.01	.01	1.5	1.5	1.5	6.7	.45	60	--	18	--
77-01-07	.17	.06	1.1	1.0	2.1	2.2	9.6	.75	--	0	--	10
77-02-02	.14	.03	.78	.72	1.5	1.5	6.8	.37	--	--	--	--
77-03-02	.48	.01	.00	.58	.58	.59	2.6	.03	--	--	--	--
77-04-06	10.8	.01	.02	.59	.61	.62	2.7	.06	--	20	--	0
77-05-02	.69	.01	.00	.61	.61	.62	2.7	.06	--	--	--	--
75-12-10	1.61	.03	.04	1.2	1.2	1.2	5.4	.02	--	--	--	--
76-02-24	13.7	.01	.02	1.1	1.1	1.1	4.9	.03	--	--	--	--
76-03-10	40.7	.01	.04	.92	.96	.97	4.3	.05	--	--	--	--
76-04-15	20.3	.00	.02	.98	1.0	1.0	4.4	.14	50	--	1	--
76-05-11	34.3	.02	.02	1.2	1.2	1.2	5.4	.07	--	--	--	--
76-06-09	.25	.21	.03	1.1	1.1	1.3	5.8	.04	--	--	--	--
77-03-02	7.43	.06	.14	1.1	1.2	1.3	5.6	.08	--	--	--	--
77-04-06	26.5	.02	.01	.85	.86	.88	3.9	.04	--	20	--	0
77-05-03	2.54	.03	.00	.68	.68	.71	3.1	.02	--	--	--	--

Table 69 --Chemical and spectrophotographic analyses of water samples from streams in the vicinity of the Pumpkin Creek study area--continued

DATE OF SAMPLE	TOTAL BERYL- LIUM (BE) (UG/L)	DIS- SOLVED BERYL- LIUM (BE) (UG/L)	DIS- SOLVED BORON (B) (UG/L)	TOTAL CAD- MIUM (CD) (UG/L)	DIS- SOLVED CAD- MIUM (CD) (UG/L)	TOTAL CHRO- MIUM (CR) (UG/L)	DIS- SOLVED CHRO- MIUM (CR) (UG/L)	TOTAL COPPER (CU) (UG/L)	DIS- SOLVED COPPER (CU) (UG/L)	TOTAL IRON (FE) (UG/L)
75-11-19	10	10	430	<10	0	20	20	20	0	260
75-12-11	--	--	420	--	--	--	--	--	--	--
76-01-15	0	--	340	<10	--	0	--	20	--	940
76-02-12	--	--	350	--	--	--	--	--	--	--
76-03-11	--	--	0	--	--	--	--	--	--	--
76-04-14	0	--	290	<10	--	10	--	10	--	180
76-05-11	--	--	350	--	--	--	--	--	--	--
76-06-09	--	--	530	--	--	--	--	--	--	--
77-01-06	--	0	450	--	4	--	10	--	1	--
77-03-02	--	--	300	--	--	--	--	--	--	--
77-04-06	--	0	220	--	1	--	0	--	1	--
77-05-03	--	--	340	--	--	--	--	--	--	--
75-11-13	10	0	350	20	1	45	0	10	0	280
75-12-09	--	--	270	--	--	--	--	--	--	--
76-01-13	0	--	350	<10	--	0	--	10	--	360
76-02-11	--	--	240	--	--	--	--	--	--	--
76-03-09	--	--	240	--	--	--	--	--	--	--
76-04-13	0	--	300	<10	--	0	--	10	--	600
76-05-10	--	--	290	--	--	--	--	--	--	--
76-06-08	--	--	420	--	--	--	--	--	--	--
76-07-13	0	--	370	<10	--	0	--	10	--	500
76-08-11	--	--	350	--	--	--	--	--	--	--
76-10-07	--	10	350	--	1	--	10	--	2	--
76-12-02	0	0	360	10	1	20	20	<10	0	990
77-01-06	--	10	300	--	1	--	0	--	2	--
77-02-02	--	--	290	--	--	--	--	--	--	--
77-03-01	--	--	290	--	--	--	--	--	--	--
77-04-05	--	0	310	--	2	--	0	--	2	--
77-05-03	--	--	420	--	--	--	--	--	--	--
75-12-10	--	--	1100	--	--	--	--	--	--	--
76-01-14	0	--	1360	10	--	0	--	10	--	560
76-02-12	--	--	1100	--	--	--	--	--	--	--
76-03-11	--	--	1000	--	--	--	--	--	--	--
76-04-14	10	--	1200	<10	--	10	--	20	--	1200
76-05-11	--	--	1100	--	--	--	--	--	--	--
76-06-09	--	--	1500	--	--	--	--	--	--	--
76-07-14	0	--	1800	10	--	10	--	10	--	550
77-01-07	--	0	1200	--	5	--	20	--	0	--
77-02-02	--	--	1100	--	--	--	--	--	--	--
77-03-02	--	--	890	--	--	--	--	--	--	--
77-04-06	--	0	910	--	2	--	0	--	2	--
77-05-02	--	--	1500	--	--	--	--	--	--	--
75-12-10	--	--	960	--	--	--	--	--	--	--
76-02-24	--	--	540	--	--	--	--	--	--	--
76-03-10	--	--	520	--	--	--	--	--	--	--
76-04-15	0	--	450	<10	--	10	--	10	--	380
76-05-11	--	--	840	--	--	--	--	--	--	--
76-06-09	--	--	880	--	--	--	--	--	--	--
77-03-02	--	--	470	--	--	--	--	--	--	--
77-04-06	--	0	580	--	1	--	0	--	2	--
77-05-03	--	--	840	--	--	--	--	--	--	--

Table 69 -Chemical and spectographic analyses of water samples from streams in the vicinity of the Pumpkin Creek study area--continued

[illegible]

Table 69 --Chemical and spectrophotographic analyses of water samples from streams in the vicinity of the Pumpkin Creek study area--continued

DATE OF SAMPLE	DIS- SOLVED NICKEL (NI) (UG/L)	TOTAL SELE- NIUM (SE) (UG/L)	DIS- SOLVED SELE- NIUM (SE) (UG/L)	DIS- SOLVED VANA- DIUM (V) (UG/L)	TOTAL ZINC (ZN) (UG/L)	DIS- SOLVED ZINC (ZN) (UG/L)	SUS- PENDE SEDIM- ENT (MG/L)	SUS- PENDE SEDIM- ENT DIS- CHARGE (T/DAY)
75-11-19	4	0	0	.4	30	30	17	.01
75-12-11	--	--	--	--	--	--	38	.02
76-01-15	--	0	--	--	30	--	384	.10
76-02-12	--	--	--	--	--	--	377	.38
76-03-11	--	--	--	--	--	--	35	.03
76-04-14	--	0	--	--	0	--	10	.01
76-05-11	--	--	--	--	--	--	6	.00
76-06-09	--	--	--	--	--	--	160	.02
77-01-06	7	--	0	.1	--	40	--	--
77-03-02	--	--	--	--	--	--	--	--
77-04-06	1	--	1	.0	--	10	--	--
77-05-03	--	--	--	--	--	--	--	--
75-11-13	3	0	0	.1	0	0	61	.02
75-12-09	--	--	--	--	--	--	12	.00
76-01-13	--	0	--	--	30	--	44	.02
76-02-11	--	--	--	--	--	--	19	.22
76-03-09	--	--	--	--	--	--	23	.09
76-04-13	--	0	--	--	0	--	57	.04
76-05-10	--	--	--	--	--	--	70	1.7
76-06-08	--	--	--	--	--	--	92	.11
76-07-13	--	1	--	--	20	--	50	.31
76-08-11	--	--	--	--	--	--	30	.01
76-10-07	7	--	0	.7	--	20	--	--
76-12-02	6	0	0	.0	10	20	--	--
77-01-06	6	--	0	.0	--	10	--	--
77-02-02	--	--	--	--	--	--	--	--
77-03-01	--	--	--	--	--	--	--	--
77-04-05	8	--	0	.4	--	20	--	--
77-05-03	--	--	--	--	--	--	--	--
75-12-10	--	--	--	--	--	--	4	.00
76-01-14	--	0	--	--	30	--	225	.08
76-02-12	--	--	--	--	--	--	42	.05
76-03-11	--	--	--	--	--	--	27	.02
76-04-14	--	0	--	--	0	--	87	.06
76-05-11	--	--	--	--	--	--	37	.03
76-06-09	--	--	--	--	--	--	36	.01
76-07-14	--	0	--	--	20	--	167	.01
77-01-07	7	--	0	.0	--	20	--	--
77-02-02	--	--	--	--	--	--	--	--
77-03-02	--	--	--	--	--	--	--	--
77-04-06	6	--	0	.4	--	20	--	--
77-05-02	--	--	--	--	--	--	--	--
75-12-10	--	--	--	--	--	--	41	.01
76-02-24	--	--	--	--	--	--	12	.06
76-03-10	--	--	--	--	--	--	12	.15
76-04-15	--	0	--	--	0	--	15	.08
76-05-11	--	--	--	--	--	--	74	.60
76-06-09	--	--	--	--	--	--	177	.01
77-03-02	--	--	--	--	--	--	--	--
77-04-06	3	--	0	.4	--	20	--	--
77-05-03	--	--	--	--	--	--	--	--



Table 70

Table 70 -Chemical analyses of water samples from selected stock reserviors

STATION NUMBER	STATION NAME		DATE OF SAMPLE	TIME	SAMP- LING DEPTH (FT)	ELEV. OF LAND SURFACE DATUM (FT. ABOVE MSL)	SPE- CIFIC CUN- DUCT- ANCE (MICRO- MHOS;
453812105403001	02S49E28AAD	STOCK RESERVOIR	PC	77-06-08	0915	1.0	957
453652105383001	02S49E35DCB	STOCK RESERVOIR	PC	77-06-07	1930	1.0	1530
453438105391701	03S49E15AD	STOCK RESERVOIR	PC	77-06-08	1800	1.0	362
453258105421001	03S49E29ACC	STOCK RESERVOIR	PC	77-06-08	1500	1.0	758

DATE OF SAMPLE	PH (UNITS)	AIR TEMPER- ATURE (DEG C)	TEMPER- ATURE (DEG C)	TUR- BID- ITY (JTU)	HARD- NESS (CA,MG) (MG/L)	NON- CAR- BONATE HARD- NESS (MG/L)	DIS- SOLVED CAL- CIUM (CA) (MG/L)	DIS- SOLVED MAG- NE- SIUM (MG) (MG/L)	DIS- SOLVED SODIUM (NA) (MG/L)	PERCENT SODIUM	SODIUM AD- SORP- TION RATIO	DIS- SOLVED PO- TAS- SIUM (K) (MG/L)
77-06-08	9.9	25.5	22.8	2	140	35	23	20	150	69	5.5	6.4
77-06-07	9.1	28.0	26.9	3	550	410	67	93	150	37	2.8	4.6
77-06-08	10.5	27.5	25.0	3	130	37	19	20	20	24	.8	9.0
77-06-08	10.3	29.5	25.6	7	150	0	18	25	110	60	3.9	11

DATE OF SAMPLE	BICAR- BONATE (HCO3) (MG/L)	CAR- BONATE (CO3) (MG/L)	ALKA- LINITY AS CACO3 (MG/L)	CARBON DIOXIDE (CO2) (MG/L)	DIS- SOLVED SULFATE (SO4) (MG/L)	DIS- SOLVED CHLO- RIDE (CL) (MG/L)	DIS- SOLVED FLUO- RIDE (F) (MG/L)	DIS- SOLVED SILICA (SIO2) (MG/L)	DIS- SOLVED SOLIDS (SUM OF CONSTITUENTS) (MG/L)	DIS- SOLVED SOLIDS (TONS PER AC-FT)	TOTAL NITRITE PLUS NITRATE (N) (MG/L)	TOTAL AMMONIA NITRO- GEN (N) (MG/L)
77-06-08	77	25	100	.0	370	.7	.4	5.3	639	.87	.01	.03
77-06-07	150	13	140	.2	700	3.7	.1	.5	1030	1.40	.01	.02
77-06-08	99	7	93	.0	91	3.2	.8	1.3	220	.30	.00	.01
77-06-08	120	40	170	.0	230	2.7	.4	.2	497	.68	.00	.01

DATE OF SAMPLE	TOTAL ORGANIC NITRO- GEN (N) (MG/L)	TOTAL KJEL- DAHL NITRO- GEN (N) (MG/L)	TOTAL NITRO- GEN (N) (MG/L)	TOTAL NITRO- GEN (NO3) (MG/L)	TOTAL PHOS- PHORUS (P) (MG/L)	DIS- SOLVED BORON (B) (UG/L)	DIS- SOLVED IRON (FE) (UG/L)
77-06-08	.46	.49	.50	2.2	.02	30	30
77-06-07	.69	.71	.72	3.2	.03	440	30
77-06-08	1.7	1.7	1.7	7.5	.05	80	30
77-06-08	2.2	2.2	2.2	9.7	.09	100	20



Table 71 -Chemical and radiochemical analyses of water samples from wells and springs

SAMPLE NUMBER (FIG. 6)	STATION	NAME			DATE OF SAMPLE	TIME	SAMP- LING DEPTH (FT)	TOTAL DEPTH OF WELL (FT)	ELEV. OF LAND SURFACE DATUM (FT. ABOVE MSL)
1	02S49E22DCCA	1 PWW-01	(SAWYER-"A")	PC	77-05-04	1730	108	118	3488
2	02S49E22DCCA	4 PWW-01C	(SAWYER-"A")	PC	77-05-05	1215	110	115	3489
3	02S49E26AACA	STOCK WELL	(SANDSTONE)	PC	76-06-29	1205	150	200	3440
4	03S49E03DADB	STOCK WELL	(COMPOSITE)	PC	76-07-01	0920	144	--	3570
5	03S49E070BDA	PWW-05	(SANDSTONE)	PC	77-05-24	1000	130	138	3418
6	03S49E08ADAC	PWW-07	(SAWYER-"A")	PC	77-06-07	1800	150	165	3510
7	03S49E08CCBD	STOCK WELL	(SANDSTONE)	PC	77-05-24	1300	140	180	3390
8	03S49E11BADC	STOCK WELL	(SAWYER-"A" & CKR)	PC	75-12-03	1400	7.0	50	3465
9	03S49E12CAAA	STOCK WELL	(SANDSTONE & COAL)	PC	76-07-14	1130	32	100	3395
10	03S49E13DADA	STOCK WELL	(COMPOSITE)	PC	76-07-14	1430	113	205	3433
11	03S49E17CCDA	STOCK WELL	(SAWYER-"A" & SS)	PC	77-06-08	1145	139	180	3420
12	03S49E19BADB	STOCK WELL	(COMPOSITE)	PC	76-07-13	1230	115	135	3395
13	03S49E218CCB	SPRING	(COAL)	PC	77-06-08	1415	--	--	3474
14	03S49E23DADC	STOCK WELL	(SANDSTONE)	PC	75-11-12	1300	38	110	3386
15	03S49E30CCDC	STOCK WELL	(COMPOSITE)	PC	76-04-21	1500	61	165	3438
16	03S49E34ABCC	SPRING	("A")	PC	77-06-08	1550	--	--	3407
17	03S49E35DCAD	STOCK WELL	(COMPOSITE)	PC	75-11-12	1130	36	120	3378

SAMPLE NUMBER (FIG. 6)	FLOW RATE (GPM)	SPE- CIFIC CON- DUCT- ANCE (MICRO- MHOS)	PH (UNITS)	TEMPER- ATURE (DEG C)	HARD- NESS (CA, MG) (MG/L)	NON- CAR- BONATE HARD- NESS (MG/L)	DIS- SOLVED CAL- CIUM (CA) (MG/L)	DIS- SOLVED MAG- NE- SIUM (MG) (MG/L)	DIS- SOLVED SODIUM (NA) (MG/L)	PERCENT SODIUM	SODIUM AD- SORP- TION RATIO	DIS- SOLVED PO- TAS- SIUM (K) (MG/L)
1	.50	3740	7.9*	11.5	160	0	36	16	910	92	32	6.0
2	1.6	3540	8.0*	11.4	120	0	29	11	870	94	35	5.6
3	10	2420	7.5	10.0	670	120	130	85	350	53	5.9	7.5
4	2.0	5350	7.6	9.5	1200	380	210	170	970	63	12	11
5	6.0	5150	6.8*	11.2	1900	1400	390	220	600	41	6.0	11
6	--	3070	8.1*	10.8	130	0	27	14	690	92	27	6.5
7	--	4450	6.9*	9.9	1300	710	260	160	550	48	6.6	12
8	1.6	1780	7.9	8.5	610	320	130	70	210	42	3.7	9.4
9	2.5	2090	7.5	8.5	720	330	--	87	190	8	3.1	6.2
10	3.0	2150	7.5	10.0	400	0	83	47	370	66	8.0	5.3
11	4.0	2430	8.1*	11.0	60	0	15	5.3	580	95	33	3.3
12	2.0	1890	8.0	12.0	76	0	18	7.6	480	93	24	3.8
13	--	2180	7.4*	20.1	600	13	110	78	330	54	5.8	7.7
14	1.5	634	7.9	8.0	350	0	64	47	15	8	.3	3.2
15	2.0	5080	7.6	11.0	910	130	190	110	1000	70	14	8.5
16	2.0	1750	6.7*	13.7	419	0	69	60	270	58	5.6	6.6
17	6.0	2930	7.8	10.5	740	130	160	83	460	57	7.4	9.1

\*pH determined in field.

Table 71--Chemical and radiochemical analyses of water samples from wells and springs--continued

SAMPLE NUMBER (FIG. 6)	DIS- SOLVED SOLIDS (SUM OF CONSTITUENTS) (MG/L)	DIS- SOLVED SOLIDS (TONS PER AC-FT)	TOTAL NON- FILT- RABLE RESIDUE (MG/L)	DIS- SOLVED NITRATE (N) (MG/L)	DIS- SOLVED NITRATE (NO3) (MG/L)	TOTAL NITRITE PLUS NITRATE (N) (MG/L)	DIS- SOLVED NITRITE PLUS NITRATE (N) (MG/L)	DIS- SOLVED AMMONIA NITRO- GEN (N) (MG/L)	DIS- SOLVED AMMONIA (NH4) (MG/L)	TOTAL KJEL- DAHL NITRO- GEN (N) (MG/L)	TOTAL NITRO- GEN (N) (MG/L)	TOTAL NITRO- GEN (NO3) (MG/L)
1	2620	3.56	160	--	--	.07	.51	2.2	2.8	2.4	2.5	11
2	2450	5.11	--	--	--	.00	.00	2.2	2.8	2.2	2.2	9.7
3	1780	--	--	.03	.10	--	--	--	--	--	--	--
4	4340	--	--	.10	.40	--	--	--	--	--	--	--
5	4170	5.67	--	--	--	.01	.05	2.1	2.7	1.9	1.9	8.5
6	2060	--	--	.11	.50	--	--	--	--	--	--	--
7	3170	4.31	--	--	--	.88	.88	.88	1.1	.90	1.8	7.9
8	1370	--	--	1.7	7.5	--	--	--	--	--	--	--
9	1390	--	--	<.02	--	--	--	--	--	--	--	--
10	1490	--	--	.35	1.5	--	--	--	--	--	--	--
11	1640	2.23	--	--	--	.25	.19	1.1	1.4	1.5	1.8	7.7
12	1360	--	--	.04	.20	--	--	--	--	--	--	--
13	1580	--	--	.44	1.9	--	--	--	--	--	--	--
14	397	--	--	.72	3.2	--	--	--	--	--	--	--
15	3990	--	--	1.1	4.9	--	--	--	--	--	--	--
16	1180	--	--	.25	1.1	--	--	--	--	--	--	--
17	2210	--	--	4.4	19	--	--	--	--	--	--	--

SAMPLE NUMBER (FIG. 6)	BICAR- BONATE (HCO3) (MG/L)	CAR- BONATE (CO3) (MG/L)	ALKA- LINITY AS CACO3 (MG/L)	CARBON DIOXIDE (CO2) (MG/L)	TOTAL SUL- FIDE (S) (MG/L)	DIS- SOLVED SULFATE (SO4) (MG/L)	DIS- SOLVED CHLO- RIDE (CL) (MG/L)	DIS- SOLVED FLUO- RIDE (F) (MG/L)	BROMIDE (BR) (MG/L)	IODIDE (I) (MG/L)	DIS- SOLVED SILICA (SiO2) (MG/L)	TOTAL FILT- RABLE RESIDUE (MG/L)
1	1560	0	1280	31	.6	860	9.5	.8	.1	.01	9.6	2600
2	1560	0	1280	25	.2	740	9.0	.9	.1	.00	9.7	--
3	671	0	550	34	--	860	4.5	<.1	--	--	10	--
4	1000	0	834	40	--	2400	9.4	.2	--	--	8.1	--
5	650	0	530	165	.7	2600	6.4	.1	.1	.01	11	4600
6	930	0	760	12	2.0	840	21	1.3	--	--	9.4	--
7	730	0	600	147	.9	1800	5.7	.9	.1	.01	11	--
8	357	0	292	7.2	--	750	7.7	.6	--	--	18	--
9	480	0	390	24	--	710	3.6	.2	--	--	12	--
10	553	0	453	28	--	700	5.1	.2	--	--	11	--
11	670	0	550	8.5	.4	680	15	.2	.1	.00	8.7	--
12	795	0	652	13	--	430	14	.4	--	--	10	--
13	715	0	586	46	--	680	8.0	.4	--	--	13	--
14	428	0	351	8.6	--	38	4.0	.5	--	--	14	--
15	947	0	776	38	--	2200	18	.4	--	--	11	--
16	663	0	544	212	1.4	430	8.0	.2	--	--	9.0	--
17	740	0	608	19	--	1100	7.2	<.1	--	--	10	--

Table 71--Chemical and radiochemical analyses of water samples from wells and springs--continued

[illegible][illegible]

Table 71-Chemical and radiochemical analyses of water samples from wells and springs--continued

SAMPLE NUMBER (FIG. 6)	SUS- PENDED GROSS BETA AS CS-137 (PC/L)	DIS- SOLVED GROSS BETA AS SR90 /Y90 (PC/L)	SUS- PENDED GROSS BETA AS SR90 /Y90 (PC/L)	DIS- SOLVED GROSS BETA AS SR90 /Y90 (PC/L)
1	7.0	<7.0	5.8	7.3
2	--	--	--	7.1
3	--	--	--	--
4	--	--	--	--
5	--	--	--	4.4
6	--	--	--	--
7	--	--	--	5.0
8	--	--	--	--
9	--	--	--	--
10	--	--	--	--
11	--	--	--	4.1
12	--	--	--	--
13	--	--	--	--
14	--	--	--	--
15	--	--	--	--
16	--	--	--	--
17	--	--	--	--

Lithologic Logs of Drill Holes

[Land-surface altitudes are referenced to mean sea level datum.  
Depth of drill hole and depth to water are reported in feet below  
land surface. Depth of drill hole is reported to the nearest foot  
where the samples were cuttings and to the nearest 0.1 foot where  
the samples were cores.]

Test well: PW-01  
Location: 02S49E22DCCA-1  
Date drilled: 10-25-76

Land-surface altitude: 3,488 ft  
Total depth: 118 ft  
Depth to water: 75 ft  
Sample source: cuttings

Water-well construction notes: Hole drilled with air circulation; cased with 4-inch plastic pipe perforated from 77 to 108 ft; formation packer at 65 ft.

<u>Depth</u>	<u>Lithologic description</u>
0-5	Clay, brown, weathered, moist; tree trunk at 3 ft
5-7	Clay, sandy, tannish-brown, moist; includes thin beds of buff siltstone stained by iron oxide
7-12	Coal, soft, moist
12-20	Claystone, black to dark-brown, plastic; grades to slightly plastic dark-gray claystone
20-22	Sandstone, fine-grained, gray
22-62	Shale, sandy, gray and bluish-gray, slightly moist; interbedded with thin firm shale
62-74	Shale, gray, firm, slightly moist
74-106	Coal, brownish-black; 1 ft shale parting at 89 ft; first 20 ft appeared unsaturated from cuttings
106-110	Shale, silty, light-gray
110-118	Shale, light-gray, hard, dry

Test well: PW-02  
Location: 02S49E24BBCD  
Date drilled: 10-20-76

Land-surface elevation: 3,649 ft  
Total depth: 125 ft  
Depth to water: 114 ft  
Sample source: cuttings and core

Water-well construction notes: Hole drilled with air and water circulation;  
not cased.

<u>Depth</u>	<u>Lithologic description</u>
0-6	Sand, fine to medium, buff, dry
6-9	Coal, dry
9-12	Shale, carbonaceous
12-22	Claystone, sandy, medium-gray to brownish-gray, moist; some iron-oxide stain
22-28	Sandstone, fine-grained, tan to light-gray, uncemented, slightly moist; alternates with gray shale; some iron-oxide stain
28-49	Sandstone, shaly, tan to brown, uncemented, slightly moist; thin well-indurated zone at 38 ft
49-69	Sandstone, fine- to medium-grained, tan to brown, slightly moist; interbedded with dark-brown sandy shale; iron-oxide stain present in shaly zones from 55 to 60 ft
69-78	Shale, sandy, tan to gray, friable, slightly moist; contains trace iron-oxide stain; grades to moist firm dark-gray shale
78.0-82.8	Shale, light-gray to gray, firm, plastic; interbedded with silty sandstone; core loss expected in sandy zones
82.8-112.2	Coal, black, dull; contains brown streaks and several badly broken zones especially along bedding planes; some vertical fractures; trace marcasite (or pyrite) on fractures in last foot of coal core; 1-inch to 1-ft core lengths; gray to carbonaceous shale parting from 95.9 to 96.1 ft
112.2-112.5	Shale, silty, light-gray; some coal flecks
112.5-120.0	Sandstone, shaly, fine-grained, light-gray, friable; grades to silty sandstone
120.0-125.0	Sandstone, silty, very fine grained, light-gray, friable, dirty

Test well: PWW-03  
Location: 02S49E28CBDC  
Dates drilled: 11-3-76 to 11-5-76

Land-surface elevation: 3,558 ft  
Total depth: 169 ft  
Depth to water: 146 ft  
— Sample source: cuttings and core

Water-well construction notes: Hole drilled with air and water circulation;  
cased with 4-inch plastic pipe perforated from  
129 to 159 ft; formation packer at 120 ft.

<u>Depth</u>	<u>Lithologic description</u>
0-2	Sand, fine, buff, weathered, dry
2-3	Clay, sandy, tan, friable; has iron-oxide stains
3-18	Sandstone, fine-grained, buff, unconsolidated, fairly clean, slightly moist; quartz predominates; some gypsum
18-32	Shale, sandy, gray and dark-gray, firm, slightly moist
32-35	Coal, brittle, slightly vitreous
35-38	Shale, light-gray
38-41	Siltstone, buff
41-45	Shale, bluish-gray, dry
45-49	Siltstone, brown, dirty
49-69	Shale, silty, dark-brown to light-gray, slightly moist; some friable layers
69-72	Shale, dark-brown
72-79	Coal, dry
79-84	Shale, dark-gray, firm
84-98	Siltstone, gray, very dirty
98-102	Shale, dark-gray, slightly moist
102-109	Sandstone, very fine grained, gray, dirty
109-124	Shale, dark-gray, hard
124.0-124.9	Shale, silty, gray to dark-gray, dry, competent, slightly calcareous; grades to shale
124.9-125.9	Shale, dark-gray, firm; lower 3 inches is carbonaceous; 2- to 4-inch core lengths
125.9-159.3	Coal, black, fibrous, broken, fairly hard; some vitreous surfaces and clay flecks; badly broken zones at 125.9 to 130.0 ft, 139.8 to 141.6 ft, and 149.6 to 151.4 ft; fractures are vertical, horizontal and 10°-20° from vertical; trace gypsum and pyrite located predominantly on vertical fracture planes, but also found on horizontal fractures from 157.5 to 159.0 ft
159.3-161.3	Shale, gray to light-gray, competent, slightly moist; trims difficult with knife; contains some coal flecks; grades to silty shale
161.3-163.9	Shale, silty, gray to light-gray, competent, dry; core lengths 6 inches to 1 ft
163.9-164.9	Shale, light-gray to olive, competent; alternates with silty shale and root structures filled with black silt; contains trace disseminated gypsum; grades to dirty siltstone
164.9-169.4	Siltstone, gray, friable, dirty; hard light-gray thin (1-inch) zones at 164.9 and 165.4 ft; contains disseminated gypsum and a few pyrite pebbles

Test well: PWW-04  
Location: 02S49E36BCCB  
Date drilled: 10-25-76

Land-surface elevation: 3,598 ft  
Total depth: 178 ft  
Depth to water: 170 ft  
Sample source: cuttings

Water-well construction notes: Hole drilled with air circulation; cased with 4-inch plastic pipe perforated from 148 to 178 ft; formation packer at 133 ft

<u>Depth</u>	<u>Lithologic description</u>
0-7	Clay, sandy, yellow; iron-oxide stains
7-9	Clay, bluish-gray, firm
9-12	Clay, yellow to buff
12-16	Sand, shaly, buff, dry
16-19	Clay, buff to gray, dry
19-20	Shale, bluish-gray
20-28	Coal, platy
28-31	Shale, dark-gray, hard
31-32	Coal
32-38	Shale, silty, dark-gray to gray, firm; contains some moisture
38-59	Shale, dark-gray to gray, firm; alternates with friable gray sandy shale containing some moisture
59-67	Sandstone, gray, unconsolidated, slightly moist
67-70	Shale, gray; grades to sandy shale
70-74	Sandstone, dark-gray, unconsolidated, slightly moist
74-75	Siltstone, well-indurated
75-79	Shale, silty to sandy, light-gray, slightly friable
79-110	Coal, brownish-black, dry; 6-inch shale parting at 92 ft
110-119	Shale, silty, light-gray, hard, dry
119-125	Shale, sandy, light-gray to gray; contains some moisture
125-129	Shale, silty, light-olive-gray, slightly moist
129-139	Shale, silty, gray, moist; alternates with dry gray shale; hard zone from 136 to 138 ft
139-146	Shale, gray, firm, slightly moist
146-149	Shale, silty, light-gray, dry
149-152	Shale, gray
152-163	Shale, silty, gray, slightly moist
163-178	Sandstone, very fine grained, gray, dirty, moist

Test well: PWW-05  
Location: 03S49E07DBDA  
Date drilled: 11-5-76

Land-surface elevation: 3,418 ft  
Total depth: 138 ft  
Depth to water: 93 ft  
Sample source: cuttings

Water-well construction notes: Hole drilled with air circulation; cased with 4-inch plastic pipe perforated from 88 to 138 ft; formation packers at 64 and 80 ft

<u>Depth</u>	<u>Lithologic description</u>
0-1	Clay, silty, buff, slightly moist
1-8	Clay, tan, firm, calcareous; orange iron-oxide stains, grades to a competent brownish-gray shale
8-13	Sand, clayey, very fine, dark-brown; contains trace gypsum; grades to carbonaceous shale
13-44	Coal, slightly vitreous, dry; 1-ft shale parting at 28 ft
44-46	Shale, light-gray, firm
46-57	Siltstone, shaly, light-gray, friable; contains trace gypsum, and some interbedded shale
57-60	Shale, silty, light-gray; grades to black shale
60-66	Shale, dark-gray, firm
66-75	Siltstone, light-gray, unconsolidated, slightly moist; thin hard layer at 70 ft
75-76	Shale, silty, gray, friable, dry
76-132	Sandstone, very fine and fine-grained, light-gray, poorly cemented; contains thin layers of shale and trace disseminated gypsum; thin hard layer at 78 ft; moist below 92 ft
132-138	Siltstone, shaly, gray, firm; first 0.5 ft very hard

Test well: PWW-06  
Location: 03S49E04AAAA  
Date drilled: 10-19-76

Land-surface elevation: 3,551 ft  
Total depth: 159 ft  
Depth to water: dry hole  
Sample source: cuttings

Water-well construction notes: Hole drilled with air circulation; not cased.

<u>Depth</u>	<u>Lithologic description</u>
0-3	Sand, buff, cemented, dry
3-19	Sandstone, silty and shaly, buff; some moisture from 5-10 ft; grades to silty shale
19-26	Shale, silty, tan, plastic, slightly moist
26-29	Coal
29-36	Shale, carbonaceous, black; grades to light-gray; con- tains orange iron-oxide stain
36-43	Shale, sandy, gray, slightly moist
43-57	Shale, dark-gray, slightly moist; alternates with light-gray fine-grained sandstone
57-60	Shale, light- to medium-gray, dry
60-90	Shale, silty, gray, dry; unit is sandy from 60 to 66 ft
90-101	Sandstone, shaly, medium-gray, slightly moist; inter- bedded with dry gray shale
101-107	Shale, sandy to silty, gray, slightly moist
107-138	Coal, hard; 1-foot black shale parting at 120 ft
138-143	Shale, sandy, light-gray, firm, friable
143-150	Sandstone, shaly, gray, friable
150-159	Shale, gray to light-gray, dry; contains some sand

Test well: PWW-07  
Location: 03S49E08ADAC  
Date drilled: 10-13-76

Land-surface elevation: 3,510 ft  
Total depth: 165 ft  
Depth to water: 128 ft  
Sample source: cuttings

Water-well construction notes: Hole drilled with air and water circulation;  
cased with 2-inch plastic pipe perforated  
from 150 to 165 ft; gravel packed.

<u>Depth</u>	<u>Lithologic description</u>
0-5	Clay, sandy, tan, firm
5-13	Sand, fine, shaly, tan to brown, unconsolidated; contains iron-oxide stains and salt veinlets
13-19	Shale, brownish-gray
19-25	Sandstone, very fine grained, buff, unconsolidated
25-28	Shale
28-29	Coal
29-33	Siltstone, dirty, tan to gray
33-39	Shale, silty, tan
39-45	Sandstone, very fine grained, brown, unconsolidated; alternates with gray shale
45-49	Claystone, silty, buff
49-58	Coal, soft
58-62	Shale, gray
62-88	Shale, silty, light-gray to gray; lower 10 ft is friable
88-98	Shale, gray, firm
98-102	Shale, carbonaceous
102-107	Coal, soft
107-122	Shale, silty, gray; contains thin hard zones of siltstone
122-152	Coal; 1-ft shale parting at 135 ft
152-165	Shale, bluish-gray

Test well: PWW-08  
Location: 03S49E14CDBA  
Date drilled: 10-22-76

Land-surface elevation: 3,520 ft  
Total depth: 139 ft  
Depth to water: 97 ft  
Sample source: cuttings and core

Water-well construction notes: Hole drilled with air and water circulation; cased with 4-inch plastic pipe perforated from 80 to 110 and 130 to 140 ft; formation packer at 68 ft.

<u>Depth</u>	<u>Lithologic description</u>
0-6	Clay, sandy, light-tan, dry
6-8	Shale, sandy, brown, moist
8-24	Siltstone, tan to brown, friable, dirty, slightly moist; contains some brown, plastic, shaly zones and trace iron-oxide stain
24-28	Shale, black to dark-gray, plastic, moist; contains secondary salts
28-43	Sandstone, very fine grained, tan; alternates with brown sandy shale and shale; many iron-oxide zones
43-45	Shale, carbonaceous
45-48	Coal
48-54	Shale, silty to sandy, gray, plastic, moist
54-69	Shale, gray, competent; alternates with fine-grained sandstone and sandy shale
69.0-69.7	Shale, dark-gray, firm
69.7-71.7	Shale, dark-gray, firm; interbedded with thin sandy shale
71.7-72.9	Shale, sandy, friable
72.9-74.9	Shale, dark-gray, competent, calcareous; interbedded with silty shale; 1.6-ft core length
74.9-75.1	Shale, gray to light-gray, competent, calcareous
75.1-77.5	Shale, silty, dark-gray, competent; 3-inch, 8-inch, and 1.3-ft core lengths
77.5-78.6	Shale, dark-gray, competent; contains some silt
78.6-80.2	Shale, carbonaceous, competent, plastic
80.2-113.7	Coal, black, brownish streaked, dull luster; weathered zones at 80.8 to 83.0 ft, 83.8 to 85.3 ft, and 87.7 to 88.4 ft; contains badly broken zones--some resulting from breakage in removing shale partings from core barrel; dry, competent dark-gray carbonaceous shale partings at 94.7 to 95.5 ft and 96.0 to 96.6 ft; shaly coal at 95.5 to 96.0 ft; gray plastic shale at 97.7 to 97.9 ft; several horizontal and vertical fractures; trace secondary gypsum and pyrite on vertical fracture planes below 98 ft
113.7-114.1	Shale; contains thin coal beds
114.1-115.7	Shale, gray, competent; contains some coal flecks
115.7-120.0	Sandstone, shaly, very fine grained, gray to light-gray, friable; unconsolidated below 117.2 ft
120-139	Sandstone, shaly, light-gray; contains some interbedded brownish-gray shale

Test well: PWW-09  
Location: 03S49E16DACA  
Date drilled: 10-13-76

Land-surface elevation: 3,575 ft  
Total depth: 179 ft  
Depth to water: dry hole  
Sample source: cuttings

Water-well construction notes: Hole drilled with air circulation; not cased.

<u>Depth</u>	<u>Lithologic description</u>
0-5	Sand, light-tan, weathered
5-10	Sandstone, fine-grained, tan, dirty, moist
10-18	Clay, sandy, tan, moist
18-29	Shale, gray to tan; contains iron-oxide stains
29-35	Siltstone, shaly, gray, slightly moist; grades to shale
35-47	Shale, dark-gray, slightly moist; dry from about 35 to 40 ft
47-48	Siltstone, light-gray, well-indurated
48-53	Sandstone, medium-grained, gray, moist
53-56	Coal, dry
56-58	Shale, carbonaceous
58-64	Sandstone, gray, poorly cemented, moist; interbedded with gray shale
64-81	Shale, gray and brown
81-82	Siltstone, light-gray, very hard, dry
82-85	Siltstone, shaly, gray; grades to silty shale
85-100	Shale, silty, gray, plastic, slightly moist
100-115	Shale, dark-gray, firm, moist; grades to light-gray silty shale
115-134	Sandstone, very fine to fine-grained, gray, poorly cemented, slightly moist; alternates with shaly sandstone
134-140	Shale, dark-gray, firm; grades to carbonaceous shale
140-168	Coal, dry; contains brown zones; has 1-ft shale parting at 150 ft; coal slightly moist below parting
168-169	Shale, black, firm
169-179	Sandstone, silty, very fine grained, light-gray

Test well: PW-10  
Location: 03S49E20BBAB  
Dates drilled: 10-14-76 to 10-15-76

Land-surface elevation: 3,462 ft  
Total depth: 104 ft  
Depth to water: 93 ft  
Sample source: cuttings and core

Water-well construction notes: Hole drilled with air and water circulation;  
cased with 2-inch plastic pipe perforated from  
80 to 100 ft; formation packer at 70 ft.

<u>Depth</u>	<u>Lithologic description</u>
0-25	Sand, fine, tan, dry; contains trace iron-oxide stain and a thin fine to medium gravel at 20 ft
25-31	Clay, silty to sandy, tan, dry; has iron-oxide zones at 25 and 30 ft
31-38	Sandstone, fine-grained, tannish-brown, poorly cemented, moist; contains iron-oxide stains
38.0-44.4	Clinker and sand(?)
44.4-45.5	Shale, dark-brown, firm; has iron-oxide stains and gypsum veinlets; 2- to 4-inch core lengths
45.5-51.7	Shale, silty, tannish-brown to gray, firm; orange and black iron-oxide veinlets on fracture planes; 2- to 8-inch core lengths
51.7-53.1	Siltstone, tan to orange, firm, dirty; 1- to 4-inch core lengths
53.1-54.9	Shale, gray, firm; 1.4-foot core lengths
54.9-55.6	Coal, black; badly broken with no discernible fracture planes
55.6-60.4	Shale, silty, dark-gray, competent; has orange iron-oxide stains on bedding planes; grades to dark-gray shale
60.4-60.5	Coal, badly broken; possible core loss
60.5-61.2	Shale, dark-gray, plastic
61.2-64.6	Shale, dark-gray, firm; fracture oriented 20°-30° from vertical
64.6-65.3	Shale, silty, gray
65.3-68.0	Sandstone, fine-grained, gray, poorly cemented; possible core loss
68.0-68.1	Shale, gray, dense, plastic
68.1-68.2	Coal
68.2-69.7	Siltstone, shaly, gray
69.7-70.4	Shale, gray, firm, plastic
70.4-100.6	Coal, black to brownish-black, fibrous, broken; contains soft zones; some vertical fracture planes; trace gypsum on fractures near 96.4 ft; competent dark-gray shale parting at 84.4 to 85.0 ft; 2- to 7-inch core lengths
100.6-100.8	Shale, silty, gray, slightly friable
100.8-103.8	Siltstone, light-gray, dirty, friable, poorly cemented; interbedded with shale

Land-surface elevation: 3,468 ft  
Total depth: 119 ft  
Depth to water: dry hole  
Sample source: cuttings

<u>Depth</u>	<u>Lithologic description</u>
0-4	Clay, sandy, tan, dry
4-10	Clay, tan, moist; contains some fine gravel
10-21	Clay, sandy, tan, firm; contains trace gypsum
21-27	Shale, brown; contains some sandy zones
27-47	Coal, dry
47-68	Siltstone, light-gray; alternates with gray shale
68-74	Sandstone, very fine grained, gray
74-86	Coal, dry
86-88	Shale, carbonaceous
88-104	Shale, silty, gray, slightly moist
104-119	Sandstone, very fine grained, gray, dirty, dry; contains trace gypsum

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